A SKETCH

OF

THE GEOLOGY OF INDIA.

BY

W. T. BLANFORD, A.R.S.M., F.R.S.,

GEOLOGICAL SURVEY OF INDIA;

BEING THE INTRODUCTORY CHAPTER TO

THE MANUAL OF INDIAN GEOLOGY

CALCUTTA:

OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING.

1879.

CALCUTTA

PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING.

8, HASTINGS STREET.

A SKETCH OF THE GEOLOGY OF INDIA.

Nature of present work — Limits — Physical geography of India — Sub division into Peninsular and Extra-Peninsular areas — Rivers of Peninsula — Mountain ranges of Peninsula — Mountain ranges of Extra-Peninsular area — Sind and Western Punjab — Himalaya — Ranges and rivers of Burma, &c. — Geological formations in general — List of Peninsular formations — List of Extra-Peninsular formations — Summary of geology — Metamorphic rocks — Transition rocks — Vindhyan series — Probable conditions of deposit — Palæozoic rocks of Salt Range — Oldest rocks of Northern Punjab, Kashmir, &c. — Oldest rocks of Himalaya — Gondwána system — Physical geography of Gondwána period — Relations of Gondwána flora and fauna — Climate of Gondwána epoch — Jurassic marine rocks — Cretaceous marine rocks — Distribution of cretaceous land — Deccan traps — High-level laterite — Tertiary coasts of Peninsula — Extra-Peninsular mesozoic rocks — Tertiary rocks — Distribution of eocene land — Later tertiary beds — Siwalik fauna — Origin of Himalayas — Origin of Indo-Gangetic plain — Distribution of recent fauna — Ethiopian affinities of Oriental mammals — Ethiopian affinities of Indian mammals — Affinities of land shells — Survival of older types in the Indian area — Glacial epoch — Sub-recent changes of level — Previous summaries of Indian geology: Calder, 1833 — Newbold, 1844 — Carter, 1854 — Greenough, 1854 — Later sketches.

Nature of present work.—The present, although by no means the first general description of the Geology of India, differs from most previous works on the subject in the extent of the area described, and from all in the amount of information in the hands of the writers. The greater number of the papers hitherto published on the Geology of the British possessions in India and the neighbouring countries have dealt only with portions of the territory; and, since the establishment of a Geological Survey by the Government of India, no opportunity has hitherto been afforded of bringing much scattered information, procured by the Officers of the Survey, but, on account of incompleteness, or for other reasons, hitherto unpublished, into connexion with the published data distributed throughout the Memoirs and Records of the Survey, and the Journals of various Scientific Societies. The urgent need for a general exposition of the present state of Indian Geology has led to the present attempt to combine the observations of all Members of the Geological Survey, past and present, with the information collected by other Geologists, and to give a general view of the existing state of knowledge on the subject.

Limits.—The limits of the country described in the present work coincide in general with those of the territory under British rule or protection: a few notes will occasionally be added on the geological features of countries beyond the boundary, wherever information is available; but this is rarely the case. There is, in general, far more reason for us to deplore the ignorance still existing of tracts in the British dominions, than to congratulate ourselves on our acquaintance with foreign territory beyond the limits of the "red line."

Physical geography of India.—Before proceeding to any geological details, it may not be out of place to glance briefly at the physical features of the region under consideration. With the general outline of the British possessions in India and Burma all are acquainted. The great triangular promontory, with the island of Ceylon south-east of its extremity, to the west of the Bay of Bengal, and the long narrow belt of country along the shore of Burma, with a broader expanse in the Irawadi valley to the southward, and the long narrow plain of the Brahmaputra to the northward, east of the Bay; the broad and high mountain chain of the Himalayas, with the loftiest peaks in the world dotted along its snowy range, stretching in a vast convex curve from west to east along the northern boundary, and forming the barrier between the tropical plains of India and the cold and barren plateaus of Tibet: all these are familiar to every one. But there are a few other peculiarities of the region intimately connected with its geological structure, and deserving of a brief notice; and as the nomenclature of the Indian mountain ranges is by no means definitely settled, it is necessary to explain terms which must frequently be used in the ensuing pages.

Sub-division into Peninsular and Extra-Peninsular areas.—The first of the peculiarities to be noticed is the great alluvial low-level plain of Northern India, watered by the Ganges and Indus and their tributaries; and hence known as the Indo-Gangetic plain. This is an immense expanse of flat country stretching from sea to sea, entirely composed of alluvial deposits of very late geological age, and dividing the hilly ground of the Peninsula from the various mountain and hill ranges of Sind, the Punjab, the Himalayas, Assam, and Burma. It will presently be shewn that this sub-division is not merely geographical, but that a trenchant distinction exists between the rocks of the Indian Peninsula and those of the *Extra-Peninsular area*, as the territories divided from the *Peninsular area* by the Indo-Gangetic plain may be termed collectively. The geological history of these regions is widely different; and even in the characters of the surface there is a marked contrast, due

to the great effects produced by disturbance in late geological times throughout the Extra-Peninsular region—an effect culminating in the elevation of the great Himalayan chain;—whilst in the Peninsula there appears to have been singularly little contortion or alteration of the strata after a very early period. The Vindhyans of Bundelkhand and Central India are certainly not newer than lower palæozoic; yet they are nearly horizontal throughout the greater part of their area; and they are far less tilted and folded than the pliocene Siwaliks along the base of the Himalayas, and of the Punjab and Sind mountains, on the opposite side of the Indo-Gangetic plain.

The first step towards a comprehension of Indian geology is this sub-division of the country into three distinct regions—Peninsular India, the Extra-Peninsular area, and the great Indo-Gangetic alluvial plain separating the two. The plain requires no further description at present; its peculiar features, many of them of singular geological interest, will be found described in the chapters relating to post-tertiary and recent formations. The physical geography of the other regions is less simple. The Peninsula is the most important portion of the British territories in Southern Asia; it comprises the greater part of India proper, and its geology has received much more attention than has that of the neighbouring countries; consequently it requires to be first noticed.

Rivers of Peninsula.—Some of the main features of India and the neighbouring countries are represented in the accompanying sketch map, on which only the principal rivers and the mountain ranges are marked. The rivers of the Peninsula are seen at a glance to comprise two well-marked groups, irrespective of the streams flowing to the Ganges: these groups are—first, the rivers running to the westward, and terminating in the Arabian Sea, the Narbada (Nerbudda), and Tapti (Taptee) being alone of sufficient importance to be noted; secondly, the rivers running to the Bay of Bengal, the principal of which are the Mahánadi (Mahanuddy), Godávari (Godavery or Godavri), Krishna (Kistna), and Cauvery (Cavery or Kaveri). It should further be observed that the only large streams running westward drain the northern portion of the Peninsula, and that, except in a narrow strip of country close to the western or Malabar coast, all the drainage south of the Tapti valley, even from the summits of the hills within sight of the western sea, runs eastward to the Bay of Bengal.

Mountain ranges of Peninsula.—The nomenclature of Indian mountain ranges is still a difficulty, it being a rare exception that any definite term is applied to a mountain chain, throughout its extent, by the people of the country. In many parts of India, peaks and passes

have names, but the ranges have none; and even if names exist, their application is not unfrequently vague. Thus the ancient name of "Vindhya," applied to the hills separating Hindustan proper or the Gangetic country from the Deccan (Dakhin or south) has now, by common consent, been restricted to the hills north of the Narbada; but it appears almost certain that the term originally applied also to the ranges now known as Sátpura, south of the river; and it is very probable that the latter hills were more especially indicated by the term "Vindhya" than the former. The term "Sátpura," again, was of very indefinite application, and probably included other ranges, besides that to which it is now restricted. The names here applied are those employed by the latest writers on Indian geography; but some of them are by no means generally adopted on maps.

The most important mountain ranges of the Peninsula are the *Sahyádri*, or Western Ghâts, running along the western coast, from the Tapti river to Cape Comorin, at the southern extremity of the Peninsula; the *Sátpura*, running east and west, on the south side of the Narbada valley, and dividing it from the drainage areas of the Tapti to the westward, and the Godávari to the eastward; and the *Arvali* (Aravalli or Aravally), striking nearly south-west to north-east, in Rájputána. The so-called *Vindhyan* range, north of the Narbada, and the eastern continuation of the same north of the Son valley, known as the Kymor range, are merely the southern scarps of the Vindhyan plateau comprising Indore, Bhopal, Bundelkhand, &c. The plateaus of Hazáribágh and Chutia Nágpúr (Chota Nagpore) in South-Western Bengal appear to form a continuation to the eastward of the Sátpura range; but there is no real connexion between these elevations and the Sátpura chain; they are formed of different rocks, and there is no similarity in the geological history of the two areas, so far as it is known. In many maps a range of mountains is shewn along the eastern coast of the Peninsula, and called the Eastern Ghâts. This chain, as a whole, has no existence, but is composed, to the southward, of the eastern scarp of the Mysore plateau, and to the northward of the south-eastern scarp of the Bastar-Jaipur plateau, north-west of Vizagapatam, and of several short isolated ridges of metamorphic rocks, separated from each other by broad plains, and having in reality but little connexion with each other. There are also several minor ranges, such as the Rájmahál hills in Western Bengal, the Indhyádri between the Tapti and Godávari, the Nallamalé (Nullamullay) near Kadapah, north-west of Madras, and the little metamorphic plateaus, such as the Shivarais (Shevroys), Pachamalé, Kolamalé, &c., scattered over the low country of the Carnatic, south-west of Madras.

The peculiarity of all the main dividing ranges of India is, that they are merely plateaus, or portions of plateaus, that have escaped denudation. There is not throughout the length and breadth of the Peninsula, with the possible exception of the Arvali, a single great range of mountains that coincides with a definite axis of elevation; not one, with the exception quoted, is along an anticlinal or synclinal ridge. Peninsular India is, in fact, a table-land, worn away by subaërial denudation, and perhaps to a minor extent, on its margins, by the sea; and the mountain chains are merely the dividing lines left undenuded between different drainage areas. The Sahyádri range, the most important of all, consists to the northward of horizontal, or nearly horizontal strata, of basalt and similar rocks, cut into a steep scarp on the western side by denudation, and similarly eroded, though less abruptly, to the eastward. The highest summits, such as Mahábleshwar (4,540 feet), are perfectly flat-topped, and are clearly undenuded remnants of a great elevated plain. South of about 16° north latitude, the horizontal igneous rocks disappear, and the range is composed of ancient metamorphic strata; and here there is in some places a distinct connexion between the strike of the foliation and the direction of the hills; but still the connexion is only local; and the dividing range consists either of the western scarp of the Mysore plateau, or of isolated hill groups, owing their form apparently to denudation. Where the rocks are so ancient as those are that form all the southern portion of the Sahyádri, it is almost impossible to say how far the original direction of the ranges is due to axes of disturbance; but the fact that all the principal elevations, such as the Nilgiris (Neilgherries), Palnés (Pulneys), &c., some peaks on which rise to over 8,000 feet, are plateaus and not ridges, tends to shew that denudation has played the principal share in determining their contour.

The southern portion of the Sahyádri range is entirely separated from the remainder by a broad gap, through which the railway from Madras to Beypúr passes west of Coimbatúr. The Anamalé, Palné, (Pulney), and Travancore hills south of this gap, and the Shivarai (Shevroy) and many other hill groups scattered over the Carnatic, may be remnants of a table-land once united to the Mysore plateau, but separated from it and from each other by ancient marine denudation. Except the peculiar form of the hills, there is but little in favour of this view; but, on the other hand, there is nothing to indicate that the hill groups of the Carnatic and Travancore are original elevations.'

The whole of the Western Sátpuras, from their western termination in the Rájpipla hills to Asirgarh, consist of basaltic traps, like the Sahyádri, the bedding being, it is true, not horizontal; but the dips are low and

irregular, and have no marked connexion with the direction of the range. The Central Sátpuras, comprising the Pachmarhi or Mahádeva hills, from the gap in the range at Asirgarh to near Narsingpur, are composed chiefly of horizontal, or nearly horizontal, traps, but partly of sandstones and of metamorphic rocks; and there is here again, as in the Southern Sahyádri, some connexion between the strike of the foliation in the latter and the direction of the ranges. The highest peaks, however—those of Pachmarhi (4,380 feet)—are of horizontal mesozoic sandstones. Farther east still the Sátpuras consist entirely of horizontal traps, terminating in the plateau of Amarkantak, east of Mandla. East of this plateau, there is, north of Beláspur, a broad expanse of undulating ground at a lower level; and farther to the eastward, again, the metamorphic plateau of Chutia Nágpúr rises, capped in places by masses of horizontal trap and laterite. These formations were once apparently continuous across the low ground near Beláspur with the same strata on an equal elevation at Amarkantak. Similar outliers occur on the Bundelkhand plateau, north of the Narbada; all tending to the same conclusion—that the low valleys of Central India are merely denudation hollows, cut by rain and rivers out of the original plateau of the Peninsula. The chief exceptions to this law—the instances in which the strike and dip of the rocks appear to have produced important effects on the contour of the country—are to be found amongst the metamorphic and transition formations.

It is true that some small ridges are formed of azoic and mesozoic sandstones, in places where the beds of these systems have been disturbed; but the only important lines of disturbance in either appear to be due to older axes of metamorphic foliation; and it is a rare case to find that the strike of the sandstones appears to have much effect upon the directions of the hills and valleys. A possible exception occurs in the Damúda valley in Bengal; but even this is a disputed case; and the subject will be discussed in the chapters relating to the Gondwána system.

This remarkable absence in the Indian Peninsula of any evidence of disturbance in late geological times—a feature which abruptly distinguishes the whole area from the remainder of Asia—will be further noticed in the sequel: at present it is sufficient to remember that the principal mountain chains of the Indian Peninsula are, with one exception, not coincident with axes of disturbance or elevation, and to note the contrast in the Extra-Peninsular area.

The Arvali differs from the other great ranges of India in being entirely composed of disturbed rocks, with the axes of disturbance corresponding with the direction of the chain. The formations found in the

Arvali range belong to the transition rocks, and are of great antiquity; for the most part they are much altered; they are quite unfossiliferous, and there is evidence which renders it probable that the elevation of the range dates from a period anterior to the deposition of the Vindhyan rocks—themselves of unknown age, but almost certainly not of later date than older palæozoic; whilst the fact that these Vindhyan rocks are found almost horizontal in the neighbourhood of the Arvali range, on both sides of the chain, shews that here, as elsewhere in the Peninsula, the forces which have affected the non-peninsular area in later geological epochs have not been felt.

Mountain ranges of Extra-Peninsular area.—Passing to the other side of the Indo-Gangetic plain—no matter whether the region reached be to the eastward in Sind and the Punjab, to the northward in the Himalayas, or to the eastward in Chittagong and Burma—the mountain ranges, with the exception of a portion of the Assam range, are everywhere composed of disturbed and contorted beds, and the disturbance has invariably affected rocks of late geological age. The amount of alteration may be small or great; the hills may consist of simple anticlinal folds, as in Sind, or of the most complicated inversions, as in parts of the Himalayas; the strike of the bedding may vary from east and west to north and south; but two characters are constant—great disturbance affecting all the formations, and the coincidence of the direction of the ranges with synclinal and anticlinal axes.

Sind and Western Punjab.—In physical characters, as in geology, there is, to some extent, a passage between the two great and contrasting regions in the Western Indian provinces of Guzerat, Kattywar (Kathiawad), and Cutch (Kachh or Kach). These districts are, however, of no great extent, and may be neglected for the present. The rocks of the Eastern Salt Range in the Punjab differ from those of the western extremity, and the former approximate to the Peninsular type. Passing on to the Extra-Peninsular area, and commencing on the west in Sind, there are to the westward of the Indus several ranges having a general north and south direction. Of these, the most important is the Khirthar, forming the western boundary of Upper Sind. But little is really known of the geography west of the frontier. The Hala range of most maps is an imaginary chain of mountains; but there are several ranges immediately to the west of the frontier, parallel to the Khirthar. Farther to the westward, however, the ranges in Baluchistan run east and west, parallel with the coast; and to the north of Sind, in the Mari and Bhúgti hills, the same east and west strike is found. These hills are still outside of British territory. The next range to the northward, the Suleimán, form-

ing the boundary of the Punjab, and extending from the frontier of Sind at Kashmor to the neighbourhood of Bannu, is again a north and south range, like the Khirthar. The Northern Punjab is traversed by a series of ranges having a general east and west strike, but being frequently curved, the curvature being greatest in the Salt Range, the most southern of all, and its continuation west of the Indus; whilst the ranges near Peshâwar and Attock are more nearly east and west. But little is known of the mountains in Afghanistan, nor have they much connexion with those of the Indian frontier: a north-east and south-west strike appears to prevail amongst them; but the Safed Koh, forming the southern watershed of the Kabul river, is said to strike east and west, like the Afridi hills and other ranges, of which it is a continuation.

Himalaya.—Throughout the western frontier of India there is a deficiency of rivers, owing to the small rainfall of the country; and no streams of any importance join the Indus from the west. The largest tributary is the Kabul river, which flows past Peshâwar, and runs into the Indus near Attock. The five great tributaries of the Indus—the Jhelum, Chinâb, Râvi, Biás, and Sutlej—flow from the Himalayas; and, after traversing the Punjab, unite to form the Punjnad, before falling into the Indus from the eastward. The Himalayas may be considered as extending from the Indus to the Brahmaputra; these two rivers between them almost encircling the mountain zone of Northern India. Both streams rise in Tibet, and within a short distance of each other, and flow, the Indus to the north-west, the Brahmaputra, here known as Sangpo (Sanpoo), first east by south, then almost due east, until each, after a long course, breaks through the Himalayan chain, and reaches the plains of India—the Brahmaputra in Upper Assam, the Indus in the Northern Punjab.

Of the great mountain zone thus defined, the western portion alone is well known; and even here the geology requires much additional study. From a little east of the 80th parallel of east longitude even the geographical details of the Himalaya are but imperfectly represented on maps. The only accessible tract, Sikkim, does not extend far beyond the first great chain, and stops short of the main watershed.

The Himalaya, considered as a whole, forms a curved belt of mountains, with their convexity to the southward, running nearly from north-west to south-east to the westward, and from west to east to the eastward, the eastern extremity striking north of east. But, besides composing a great mountain chain, or series of chains, the Himalayas form the southern scarp of the Tibetan plateau—a tract of highland from about 12,000 to 16,000 feet above the sea. The northern scarp of this plateau is formed

by the Kuenlun, overlooking the lower plains of Eastern Turkestan and the Gobi desert.

The western terminal portion of the Himalayan chain—the only part, as already stated, that has been accurately mapped—comprises a number of great ranges, the majority of which have no settled appellations, but are commonly known by the terms applied to passes through them, or by the names of the districts traversed. The principal of these ranges are the Mustágh, Ladák, Zánskár or Báralácha, and Pir Panjál. The Mustágh, frequently called the Kárákoram, from a well-known pass, which, however, does not cross the range itself, forms the northern watershed of the Indus and its tributary the Shayok, and separates their drainage area from the upper waters of the Yárkand river. To the north-west the Mustágh range appears to curve round into the northeast-southwest chain of the Hindu Kush, and is of great height; its culminating peak, the nameless summit known on the Great Trigonometrical Survey maps as K2, rising to an elevation of 28,278 feet, and being only second to Mount Everest. The Ladák range intervenes between the Indus and Shayok. The Zánskár (Záskár) or Báralácha (Baralatsé) range divides the Upper Indus from the Jhelum and Chináb; the north-western continuation forming the northern boundary of the Kashmir valley, and terminating in the peak of Nanda Parbat. The Pir Panjál divides the Kashmir valley, drained by the Upper Jhelum, from the plains of the Punjab. All these ranges, it should be recollected, have a north-west to south-east direction; and to the westward there is a singularly abrupt change in the strike, as in the instance already mentioned, of the angle formed by the Mustágh range and the Hindu Kush. The angle made by the meeting of the Pir Panjál range, east of the Jhelum, and of the Murree and Hazára hills, west of that river, is even sharper; the latter ranges running at first north and south, forming an acute angle with the Pir Panjál, and then curving round south-west, and finally to west.

It is doubtful whether any of the ranges already noted in the terminal area should be considered the prolongation of the main Himalayan axis, although, if any be really a continuation of the Himalayas proper, it is either the Pir Panjál or the Zánskár range. The main range of the Himalayas appears more probably, so far as geological structure affords a clue, to commence on the westward in the Dhauladhár, a minor ridge rising from the banks of the Rávi close to Dalhousie, and extending to the east-south-east, till it rises into the main snowy range of the North-West Himalayas. Many geographers distinguish two parallel ranges from the neighbourhood of Simla to the eastward: the snowy range

proper, formed of the highest peaks; and a more northern ridge, forming the watershed between the Tibetan plain and the rivers running to the plains of India. Others consider the latter to be the true Himalayan range, and look on the higher peaks as belonging to the spurs between the rivers flowing from that range. It is certain that the great peaks, such as Nanda. Devi (25,700 feet), Dhaulagiri (26,826 feet), Mount Everest (29,002 feet), Kinchinjinga (28,156 feet), Chumalari (23,929 feet), &c., are separated from each other by deep valleys through which flow streams coming from the northern range, and that, although the peaks of the latter are inferior in elevation, the passes by which it is traversed are much higher; but it has not yet been ascertained whether the great peaks are on the strike of any continuous band of rock, or whether they merely consist of hard nuclei left undenuded.

Along the southern base of the Himalayas, and parallel with the general direction of the mountains, a series of comparatively low ridges extends, formed of tertiary rocks, and separated from each other or from the rocks of the main range by valleys called dúns. These fringing ranges of the later formations are known generally as the Sub-Himalayas; the most important being the Siwalik hills, a term especially applied to the hills south of the Deyra Dún, but frequently employed in a wider sense than its original application. To the eastward, the Sub-Himalayan ranges are less conspicuous than to the westward; but they are only locally wanting altogether, and are to be traced almost throughout the Himalayan border, from the Punjab to Upper Assam. The rivers running from the Himalayas to the Ganges and Bráhmaputra, although in many cases of considerable size, are in general formed by the union of a number of comparatively unimportant hill streams; the largest and best known of these rivers, beginning from the west, are the Gogra (Ghogra), Gandak, Kosi (Koosee), and Tista (Teesta).

Ranges and rivers of Burma, &c.—The hills immediately south of the Bráhmaputra belong to two distinct systems. The chain, known collectively as the Assam range, and locally as the Gáro, Khási (Khasia or Cossya), Jaintiá (Jyntia), and Nága hills, runs east and west to the westward and turns to north-east to the eastward, being nearly parallel to the Himalayas throughout. The western part of this range, like the hills of Kattywar and Cutch to the west of the Peninsula, presents a remarkable combination of peninsular and extra-peninsular rocks. It will be shewn that in this direction also some of the peninsular formations are found at the base of the Himalayas; but the peculiarity of the Gáro and Khási hills is, that there is less marked coincidence between the strike of the newer rocks and the direction of the range than in the

extra-peninsular area generally. To the eastward, in the Nága hills, the usual connexion between the strike of the rocks and the direction of the ranges reappears; and a monoclinal axis may be traced along the southern face of the Jaintiá, Khási, and Gáro hills themselves; but the greater portion of the latter form a plateau, on which the mesozoic and tertiary formations are horizontal, or nearly horizontal. The most important ridge of the Nága hills is the westernmost portion, known as the Barail-Pátkai range; and this chain is distinctly cut off from the western plateau of the Assam range by an abrupt change of dip in the rocks, and geographically by deep valleys.

The Súrma (Soorma) or Bárak river drains the southern slopes of the Assam range, and divides it from the great hill region of Burma. In North-Eastern Manipur (Munecpoor) there is a transition from the north-east—south-west strike of the Nága hills to the north and south (or north-by-west to south-by-east) direction of the Burmese mountain chains. The north and south direction is nearly constant throughout British Burma, and continues, curving to the south-east, in the Malay Peninsula. The great Burmese rivers, the Irawadi and Salwin, and the less important streams, the Sittoung, Tenasserim, &c., ran from north to south; and the principal hill ranges are the Arakan Yoma, between the Irawadi and the sea; the Pegu Yoma, between the Irawadi and Sittoung; and a number of less defined chains, formed of older rocks, east and west of the Salwin and throughout the Tenasserim provinces. None of these ranges within British territory attain a height exceeding 7,000 feet.

Geological formations in general.—After the above brief sketch of the more conspicuous geographical features of India and the surrounding countries—a sketch in which one of the most important distinctions between the peninsular and extra-peninsular areas has been pointed out—it will be well to proceed at once to a comparison of the geological formations found in the different regions. The contrast here will be found quite as great as in the case of the physical geography. Throughout the peninsular area, there is, from the lowest to the highest formation, a most remarkable deficiency of fossiliferous marine rocks; the few that occur being almost exclusively found in the neighbourhood of the present coast, or else in the desert between the Arvali chain and the river Indus. With one solitary exception—that of some cretaceous beds occupying a limited area in the Narbada valley—no instance is known of marine fossils being found in the Indian Peninsula, to the south-east of the Arvali range, at a greater distance than 70 miles from the coast.

The absence of marine fossils is certainly not due to the alteration the strata have undergone, nor to the deficiency of rocks suited for the

preservation of organic remains. Land and freshwater organisms are found in considerable quantities in some of the mesozoic and cænozoic formations; and it is possible that the lowest fossiliferous Gondwána beds may be of upper palæozoic age. Even at a lower horizon, in the ancient Vindhyan formation, limestones and shales, to all appearance perfectly adapted for the preservation of fossils, occur in profusion; and it is surprising that no trace of organic remains has ever been detected in the transition series, many of the slates, shales, and limestones being no more altered than some of the older fossiliferous beds of Europe, and even of the Himalayas. When it is recollected how long the "grauwacke" of Western Europe was supposed to be unfossiliferous, some faint hope may still survive that fossils may yet be found in the Vindhyan and transition rocks of India; but the European Silurian and Cambrian beds yielded organic remains in abundance to the first attempt at systematic exploration; whilst the Vindhyans, Bijáwars, Kadapahs, Karnuls, and other ancient Indian formations have been searched repeatedly, but without success, by experienced geologists, who had throughout their lives been engaged in similar researches. It cannot be said that the search is hopeless, in the Upper Vindhyans especially; but it may fairly be doubted whether any conspicuous marine organisms, such as mollusca, corals, or crustacea, will be detected.

Of the few marine beds hitherto found in the Indian Peninsula, none are older than jurassic. Even the jurassic marine beds are well represented only in Cutch and the neighbouring countries, the known representatives of the series on the eastern coast of the Peninsula being but poorly developed. The cretaceous marine rocks are better represented; although a considerable portion of the series is wanting, and the area occupied is very small. The marine beds of the tertiary period are also, so far as is known, very ill-developed, or wanting, except in Guzerat and Cutch.

In the extra-peninsular area, on the other hand, marine fossiliferous rocks of silurian, carboniferous, triassic, jurassic, cretaceous, eocene, and miocene age have been found; and in many cases a complete sequence of the different sub-divisions of each epoch has been detected; although far less time and labour have been devoted to the examination of the country than have been given to the Peninsula, and although the geology of the area is in general much more complicated, and the task of surveying surrounded by greater difficulties.

List of peninsular formations.—The following is a classified list of the formations in the Indian Peninsula, inclusive of Kattywar and Cutch. The great European sub-divisions of the geological sequence—palæozoic, mesozoic, and tertiary or cænozoic—are ill adapted for the classification of

the Indian beds; and in several instances, as will be shewn more fully in other chapters of this work, the correlation of the strata found in the Peninsula of India with the geological series elsewhere is far from satisfactorily decided. The lower formations in this list are simply classed as azoic. The sub-divisions are not always strictly consecutive; some of the marine cretaceous rocks being of the same age as the Deccan traps, and the marine jurassic beds being contemporaneous with the Upper Gondwánas.

Classified List of Formations in Peninsular India.

			Approximate maximum thickness.
Recent and post-Tertiary.		Blown sand. Soils, including black soil or regur.	Unknown; 700 feet
		Modern alluvial deposits of rivers, estuaries, and the sea coast. *Khádar* of Indo-Gangetic plain, &c.	
		Raised shell beds of coast.	
		Low-level laterite. Older alluvial deposits of Ganges, Narbada, Godávari, &c. Cave deposits.	boring.
Tertiary		Miliolite of Kattywar. Pliocene, miocene, and eocene (nummulitic) beds of Cutch and Guzerat. Sandstones, clays, and lignites of the west coast, Travancore and Ratnagiri. Cuddalore sandstones. High-level laterite.	2,700
Deccan trap series.		Upper traps and intertrappeans of Bombay. Middle traps. Lower traps and intertrappeans of Central India, Rájámahendri, &c. Lameta or infratrappean group. Infratrappeans of Rájámahendri.	6,000
Marine cretaceous rocks.		Arialúr, Trichinopoly, and Utatúr groups. Bágh beds. Neocomian of Cutch.	3,000
Marine jurassic rocks.		Umia, Katrol, Chári, and Pachham groups of Cutch. Jesalmir limestones. Tripetty and Ragavapuram beds of east coast.	6,000
Gondwána system.	*Upper*	Cutch and Jabalpur. Rájmahál and Mahádeva.	11,000
	Lower	Panchet. Damúda:—Rániganj or Kámthi, ironstone shales, and Barákar. Karharbári and Tálchir.	13,000
Vindhyan series.	*Upper*	Bhánrer (Bundair). Rewah. Kaimur (Kymore).	12,000
	Lower	Karnul. Bhima. Son. Semri.	2,000 ?
Transition or sub-metamorphic rocks.	*Upper*	Gwalior, Kadapah, and Kaladgi series	20,000
	Lower	Bijáwars. Champanír beds. Arvali. Maláni beds. Transition rocks of Behar and Shillong (the last extra-peninsular).	
Metamorphic or gneissic.		Gneiss, granitoid and schistose rocks, &c.	

The following is the succession of the more important fossiliferous peninsular rocks, the marine beds being omitted from the sequence, but classed as equivalent to their supposed representatives amongst the formations without marine fossils :—

		Peninsular rocks.	*Supposed marine equivalents.*	
			Indian.	European.
CÆNOZOIC		High-level laterite . .	Nummulitic	Middle eocene.
	Deccan Traps.	Upper Deccan traps .	?	Lower eocene.
		Middle traps	Arialúr	Upper chalk.
		Lower traps	Trichinopoly	Lower chalk.
		Infratrappeans or Lameta	Bágh beds, Utatúr.	Upper greensand.
MESOZOIC			Umia and Katrol. Chári and Pachham.	Jurassic.
	Gondwána.	Jabalpur and Cutch. Mahadeva and Rájmahál		
		Panchet		Triassic.
PALÆOZOIC		Damúda . . . . . Tálchir	. . . .	Upper palæozoic ?

It will be seen at once that the geological horizon of the upper mesozoic and tertiary beds is ascertained with a fair amount of precision; but that the determination of the position in the series to be assigned to the Lower Gondwána formations is far more doubtful, and that nothing is known of the age of the Vindhyans and older rocks.

List of Extra-Peninsular formations.—Owing partly to imperfect knowledge of the ground, but still more to the extent to which the different tracts of Extra-Peninsular India comprised in British territory are isolated and separated from each other by such regions as Nepál and Afghanistan, entirely inaccessible to Europeans, the correlation of the various formations in the extra-peninsular region with each other is more imperfect than in the peninsular area. This circumstance, however, in no way affects the contrast between the rocks in the two areas. The interstratification in Kattywar and Cutch of certain peninsular formations with marine beds belonging to the extra-peninsular types has already been noticed; but the geology of Kattywar is as yet but imperfectly known, and the only peninsular formations found in Cutch are of newer mesozoic or tertiary age. A thin representative of the Deccan trap is also found in Sind. At the eastern end of the Salt Range in the Punjab are found several groups of unfossiliferous sandstones, having some resemblance in general character to the Gondwána and Vindhyan systems of the Peninsula; and as the age of some of the Eastern Salt Range groups is approximately determined by the interstratification amongst

them of beds representing the fossiliferous marine rocks of the western portion of the range, some clue may perhaps here be afforded to the age of the peninsular rocks. Hitherto, however, no such clue has been obtained; the Salt Range is at a considerable distance from all the Gondwána and Vindhyan rocks of the Peninsula, and none of the unfossiliferous Salt Range groups has as yet been identified with any of the peninsular formations.

With the exception of Sind, there are but two localities in Extra-Peninsular India where peninsular rocks are found. One of these is at the base of the Himalayas, in Sikkim and Bhután, where fossiliferous Damúda (Lower Gondwána) beds occur. The other is in the Assam hills (Khási and Gáro), where representatives of the metamorphic and cretaceous (marine) rocks of the Peninsula, and in all probability of the transition beds and of the Rájmahál traps, are found. But, in the first instance, the relations between such Himalayan rocks as are associated with the Damúdas and those of other parts of the Himalayas are extremely doubtful; and it is not even conclusively settled whether the Himalayan rocks in question are higher or lower in position than the Damúda beds themselves; and in the Assam hills none of the older Himalayan formations have been detected: they appear to be replaced by peninsular types.

Of the extra-peninsular rocks two lists are given below: in the first, the representatives of different geological horizons in the various tracts are enumerated; and in the second, an attempt has been made to exhibit the probable correlation of the rocks in the different parts of the area, so far as the information available extends. In both lists, an asterisk serves to shew that a formation is unfossiliferous, and a note of interrogation that the position is doubtful.

CLASSIFIED LIST OF FORMATIONS IN EXTRA-PENINSULAR TERRITORIES BELONGING TO INDIA.

RECENT AND POST-TERTIARY.	. Alluvial and lake deposits. Sub-Himalayan high-level gravels.*
PLIOCENE	. Upper Manchhars of Sind. Upper and middle Siwaliks of Sub-Himalayas, Punjab, &c. Mammaliferous deposits of Western Tibet. Dehing group* of Assam. Fossil-wood deposits of Pegu.
MIOCENE	. Lower Manchhars and Gáj of Sind. Murree beds* (in part). Náhan.* Tipam group of Assam?* Pegu group of Burma.

EOCENE	*Upper* .	Nari group of Sind. Kasauli and Dagshai* groups of Sub-Himalayas.
	Middle .	Nummulitic limestone of Sind, Punjab, Assam, Burma, &c. Khirthar of Sind. Subáthu of Sub-Himalayas. Indus or Shingo beds of Western Tibet. Coal-measures of Assam ?
	Lower .	Ranikot beds of Sind. Lower nummulitics of Salt Range.
CRETACEOUS	*Upper* .	Deccan trap.* *Cardita beaumonti* beds and cretaceous sandstones of Sind. Olive group of Punjab Salt Range. Disang group* of Assam ? Upper cretaceous of Khási Hills. Negrais beds of Burma ? (*N.B.*—It is not certain that some of these formations may not be, in part at least, eocene.)
	Middle .	Hippuritic limestone of Sind. Cretaceous beds of Mount Sirban in Hazára and of Kohát. Chikkim beds of North-Western Himalayas. Cretaceous beds of Assam, in part. Mai-i group of Burma.
	Lower or *Neocomian*.—	Beds in Chichâli Pass, Salt Range.
JURASSIC	*Upper* .	Salt Range. Gieumal and Spiti beds of Northern Punjab and North-Western Himalayas.
	Middle .	Variegated group of Salt Range. Part of Spiti shales in North-Western Himalayas ?
	Lower or *Lias*.—	Upper Tagling limestone of North-Western Himalayas. Sylhet trap ?*
TRIAS	*Upper including Rhætic*.—	Lower Tagling limestone of North-Western Himalayas. *Nerinæa* beds of Mount Sirban, Hazára. Pára limestone of North-Western Himalayas. Beds with *Megalodon* and *Dicerocardium* at Mount Sirban, Hazára.
	Middle .	Salt Range ? Liláng series of North-Western Himalayas and Kashmir. Axial group of Burma ?
	Lower .	Ceratite beds of Salt Range. Infra-triassic* of Hazára, in part ?
PERMIAN & CARBONIFEROUS.		Salt Range carboniferous limestone. Damúdas of Sikkim and Bhután ? Infra-triassic* of Hazara ? Kiol limestone* of Pir Panjál ? Król* limestone and Infra-Król* of Western Himalayas ? Kuling series of North-Western Himalayas and Kashmir. Maulmain group of Burma.
SILURIAN .		*Obolus* beds of Salt Range. Attock slates* of Upper Punjab ? Slates* and traps* of Pir Panjál and Kashmir? Muth and Bhábeh series of North-Western Himalayas. Blaini* and Infra-Blaini* of Simla area ?
INFRA-SILURIAN.		Salt marl* of Salt Range ? Gneiss* of Pir Panjál and Ladák. Upper gneiss* of Zánskár range. Shillong series* of Assam hills ? Mergui group ?*
		Lower or central gneiss* of Himalayas. Gneiss* of Assam and Burma.

The thickness of the different formations has only been determined in a few instances; so few that it is useless to quote them. The amounts are very great, the tertiary rocks alone attaining a vertical development in places, as in Sind, of nearly 30,000 feet.

	Sind.	Punjab Salt Range.	Northern Punjab.	N. W. Himalaya and Tibet.	Lower Himalaya and Sub-Himalaya.	Assam.	Burma.
Pliocene	Manchhar	Siwalik	Siwalik	Mammaliferous beds	Siwalik	Dehing group*	Fossil-wood group.
Miocene	Gáj	.....	Murree beds*	..	Nahán*	? Tipam group*	Pegu group
Eocene	Nari, Khirthar	Nummulitic	Nummulitic	Indus or Shingo beds	Kasauli & Dagshai*, Subathu	Nummulitic and coal-measures.	Nummulitic.
	Ranikot	Lower Nummulitic	?	.....	... ..	.....	.....
Cretaceous	Deccan trap*, Olive shales & sandstones, Hippuritic limestone.	Olive group	?	.....	.....	? Disang group*	? Negrais group.*
	. ...	Neocomian	...	.....	.....	... ..	.....
	.....	Upper Jurassic	Upper Jurassic	Gieumal sandstones	.....	.....	.....
Jurassic, including Lias	... ..	Middle Jurassic (Kelloway)	?	Spiti shales.	.....	. .	.....
	.....	.... .	.....	Upper Tagling limestone.	.	Sylhet trap*	... ..
	.....	.. . .	*Nerinæa* beds	Tagling limestone	. ....	... ..	. ....
Triassic, including Rhætic	...	.. ..	Upper trias of Mount Sirban.	Pála limestone	... ..	. .	.....
	.....	Middle trias	. ....	Lilang series	... .	.....	Axial group.
	....	Lower trias	? Infratriassic & Tanol*	?	? Damúdas	...	...
Carboniferous	.....	Carboniferous limestone.	.....	Kuling series and ? Kiol limestone.*	? Król* and Infra-Król.*	... ..	Maulmain series.
Silurian	... ..	. ..	.	Muth series	? Blaini*	... .	. ....
	.....	*Obolus* beds	? Attock slates*	Bhábar series	? Infra-Blaini*	..	.....
Infra-Silurian	.....	? Salt marl*	Metamorphic*	? Upper gneiss*	..	? Shillong series*.	? Mergui series.*
	.....	.....	. ..	Lower or Central gneiss*	Gneiss*	Gneiss*	Gneiss.*

Summary of geology.—With these data before us, we may proceed to a brief summary of the geological history of India. This summary will serve to shew that, despite the imperfection of the geological series developed in the Peninsula, there is evidence of a singular permanency of conditions and freedom from severe disturbance at all periods after early palæozoic times. Up to the tertiary epoch the same absence of contortion appears to have prevailed in the extra-peninsular area also, but in later geological times extensive disturbance has affected many parts of the latter country. In this summary, it will be necessary frequently to anticipate arguments used in the succeeding chapters, in which, however, fuller details will be given.

Although, as has already been said, no marine fossils of older date than jurassic have been found in the Indian Peninsula, it by no means follows that the ancient azoic rocks are not of marine origin. All that can be said of the peninsular gneissic and transition series is, that they are ancient sedimentary beds: whether deposited in the sea or in rivers or lakes, it is impossible to tell. The rocks of these formations may have been originally fossiliferous; for the amount of alteration they have undergone would have sufficed in many cases to obliterate all traces of organic remains; but the absence of fossils in the much newer Vindhyans is not so easily explained; and even some of the transition beds are not more altered than rocks in which fossils have elsewhere been detected.

Metamorphic rocks.—The gneissic rocks of the Indian Peninsula are developed in three areas—the peninsular area proper, comprising the greater portion of Bengal and Madras, the Bundelkhand, and the Arvali—and appear to include representatives of two formations at least, differing in age. The older, which will be described as the Bundelkhand gneiss, is shewn to be more ancient than the gneissic formation throughout the greater part of India, by the circumstance that certain transition rocks rest without alteration and unconformably on a denuded surface of the former, but are altered and intersected by granitic intrusions in the neighbourhood of the latter; so that there is to all appearance a passage between the transition beds in question and the peninsular gneiss. It is manifest that the Bundelkhand gneiss was altered before the deposition of the Bijáwar transition rocks, and it appears probable that the peninsular gneiss was metamorphosed after Bijáwar times; and it is a reasonable inference that the peninsular gneiss, whether composed of altered Bijáwar rocks or not, is the later of the two gneissic series in origin as well as in period of metamorphism. The relative age of the gneiss occupying the Arvali area in Rájputána is uncertain.

There are no data known by which the relations of the oldest Himalayan rocks to the metamorphic formations of the Peninsula can be determined. There is a well-marked mineralogical distinction between the older gneiss of the Himalayas and both of the peninsular types—that of Bundelkhand and that of the Peninsula proper. The most important differences are, that the Himalayan gneiss is usually white or grey, the common felspars being orthoclase and albite, whilst the ordinary peninsular gneiss is pink, the prevailing felspars being orthoclase and oligoclase; and that the former rock is more micaceous, whilst the latter contains more hornblende. The Himalayan gneiss, too, is, as a rule, more uniform in character; it contains far more mica schist, but less quartzite, and very little hornblendic or syenitic gneiss; whilst in the peninsular forms of the rock the different beds vary greatly in mineral characters, and a highly hornblendic variety is much more prevalent than mica schist.

The metamorphic rocks of the Assam hill range belong, as has already been mentioned, to the same mineralogical type as the Bengal gneiss; and hills of this rock are found in places rising out of the alluvium of the Assam valley, close to the base of the Himalayas. The gneissic rock of Assam and that of the Himalayas are nowhere seen in contact; but the distinction in mineralogical character is absolute. In the absence of any contact-section there is, however, no clue to the relative age of the two series: it is impossible to say whether the Himalayan gneiss is older than that of the Peninsula, or *vice versâ*. It should also be recollected that the gneiss of the Western Himalayas is divided from that of the mountains north of Assam by nearly 500 miles of unexplored country in Nepál.

The contrast between the peninsular and extra-peninsular regions begins thus with the oldest known rocks; but it is evident that the limits of the areas were then different from what they subsequently became. Not only are the metamorphic formations of the Assam hills similar to those of the Peninsula, but the gneiss of Burma resembles the peninsular type rather than the Himalayan.

Although the metamorphic rocks are frequently granitoid, true granite only occurs amongst them in the form of veins; no large areas are known. Granitic intrusions are of larger dimensions in the older submetamorphic or transition rocks than in the gneissic series.

Transition rocks.—The transition or submetamorphic rocks of India consist of schists, slates, quartzites, breccias, limestones, &c.; they occupy a considerable area, and attain a very great thickness, but their history is as obscure as is that of the gneiss. They have been classed in two

sub-divisions: the first, which is supposed to be the older, exhibiting by partial metamorphism, conformable sequence or granitic intrusion, a close connexion with the gneissic strata; the second, shewing no such relation. The transition rocks are also divided into several groups, distinguished as much by locality as by mineral characters. All these details will be found in the second and third chapters of the present work: the only points of importance to be now noticed are the relations between the transition series, as a whole, and the older and newer rocks of the Peninsula.

The most important of these relations may be summed up in the fact that some of the transition beds appear to have been deposited previously to the last great disturbances that affected the strata of the Peninsula; whilst later beds, when tilted or contorted, are only affected within limited areas. Faults of considerable magnitude have certainly been formed at a subsequent period; but still the great lines on which the rocks of the Peninsula have been moulded were more than traced before the transition epoch had passed away: they were so firmly laid down, that they have determined the main features of the land, wherever these are dependent on the strike of the rocks; and it is remarkable how often the minor disturbances of a later date conform to the direction of the foliation in the metamorphic rocks. For although, with the exception of the Arvali, the great ranges of the Indian Peninsula appear almost solely due to the action of denudation, and although the direction of these ranges is independent of the strike of the newer rocks of which the hills themselves are composed, many of the minor ranges and of the smaller river valleys coincide in direction with the foliation of the gneiss, or the stratification of the older transition rocks. It matters little whether the gneiss foliation be due to bedding or cleavage: if the former, the high angles are evidence of great lateral pressure; if the latter, the very existence of cleavage proves the same; and the parallelism of the foliation throughout large areas, and sometimes over hundreds of miles, as in the Narbada valley, shews how extensive were the disturbing causes to which this uniformity of result is due. It is far from improbable that great mountain ranges were formed in the Indian Peninsula before the dawn of geological history, as recorded by organic remains, and that the small ridges of metamorphic and transition rocks now remaining are but the remnants that have escaped denudation.

It is difficult to say how far the eruption of igneous rocks is connected with areas of disturbance: the problem has not yet been solved. Independently, however, of the granitic intrusions already noticed, igneous rocks, often to all appearance of contemporaneous origin, are almost everywhere associated with the transition strata. Diorite or an allied

rock, often greatly altered, is found in the Shillong transition series, the beds of Chutia Nágpúr (Chota Nagpore), the Bijáwars of Bundelkhand and the Narbada valley, the Gwalior, Arvali, and Champanir beds, and the Kadapah (Cuddapah) series; whilst the Maláni transition beds are chiefly composed of felsites. Many of the "trappoid" rocks associated with the various transition strata, to judge by the descriptions given, have the characters of altered subaqueous volcanic tuffs; and this may indicate that the associated transition beds are of marine or lacustrine origin. In fluviatile, as in other subaerial deposits, the character of the associated volcanic rocks would probably be different. Some of the transition igneous rocks, however, have not the characters of subaqueous tuffs.

Vindhyan series.—The break between the uppermost transition beds and the quartzite sandstones, shales, and limestones of the Lower Vindhyans does not appear to be very great; for although the two series are nearly always unconformable, where the newer is seen to rest upon the older, there are several obscure sections indicating passage; and in the Godávari valley it has hitherto proved impracticable to distinguish the limits of the two series with certainty. The Vindhyans, however, and especially the Upper Vindhyans, have a far more recent aspect than the transition rocks: a distinction due doubtless to the much smaller amount of disturbance, and consequent alteration experienced by the newer series. It is an exception to find the Vindhyans, upper or lower, dipping at high angles; and over large areas these rocks are nearly horizontal.

The thickness of 2,000 feet assigned as a maximum to the Lower Vindhyans is probably too little; but still they are far inferior in development to the underlying transition beds and to the overlying Upper Vindhyans. It is the more surprising on this account to find that the Lower Vindhyans have so great a horizontal extension, and that they are found, with but small change in mineral character, from the Son valley to Kadapah in one direction, and to the neighbourhood of Bijápúr in another, a distance in each case of 700 miles. In the Son area, too, some peculiar beds of trap-like rock occur, similar to those already noticed as being intercalated in the transition series of Gwalior, Kadapah, and other places, and as having the characters of subaqueous volcanic tuffs. These facts are in favour of the marine origin of the Lower Vindhyans. But, on the other hand, the area occupied by this series is not continuous; and in one locality at all events, south of the Son valley, there are indications of an ancient barrier between different basins of deposition, whilst the singular absence of organic remains is rather in favour of freshwater origin; freshwater beds being, as a rule, less fossiliferous than

marine. At the same time, there is always a possibility that these formations may have been deposited at an epoch anterior to the existence of life; although, in face of the great probability that the earliest forms of organised beings existed long anterior to the appearance of *Brachiopoda* and *Crustacea* in the Cambrian formation, and even of *Foraminifera* in the Laurentian, the likelihood of the Vindhyans dating from a time when the world was devoid of life appears small. It is possible that the tropics were too hot for life, even after the polar regions and temperate zones were inhabited; but this is open to question on physical grounds, and appears contradicted by the similarity of silurian fossils in the southern hemisphere to those in the northern. Had life originated independently in both hemispheres, a wide divergence of forms might have been anticipated in the earlier formations between the two areas on opposite sides of the equator. At the same time, it is quite possible, and even probable, that marine life existed long before the fresh waters and the land were inhabited; and the land and fresh waters of the tropics may have been too hot for animals or plants after the sea teemed with living beings. Unfortunately, the first element of the question,—the enquiry whether the direction of the earth's axis has been constant, and consequently whether the present tropics have always been in the neighbourhood of the earth's equator,—has not been decided by mathematicians; and it will be shewn presently that there are some very curious indications of a low temperature having prevailed in the Indian area at very ancient epochs.

The Upper Vindhyans, consisting chiefly of fine, hard, red sandstone, with subordinate bands of shale and limestone, are quite parallel, and apparently conformable, to the lower, as a rule; but still there is extensive overlap of the lower by the higher series, and some amount of local unconformity, shewn by the presence of detritus, derived from the older beds, in the conglomerates of the newer. The area of the Upper Vindhyans is almost restricted to the great tract extending from Behar to the Arvali hills; and differs so greatly from that of the Lower Vindhyans, that a great change probably took place in the area of deposition in the interval between the formation of the two; whilst there is much in the peculiar conditions of the rocks, and in the features of the boundary, to indicate that the Upper Vindhyans may have been deposited in a land-locked area. The persistent red colour of the Vindhyan sandstones may perhaps also indicate deposition in an inland basin; for although Professor Ramsay's views on the subject[1] are not universally conceded, there can be no doubt that the old and new red sandstones of England, and

[1] Q. J. G. S., 1871, pp 197, 241.

many similar rocks elsewhere, were in great part formed in lakes or lagoons, and not in an open sea. The same observation applies, though less generally, to the Lower Vindhyans and many of the transition rocks; several of the beds, and especially the sandstones or quartzites, having the same red colour as the Upper Vindhyans.

It has already been intimated that the elevation of the Arvali range probably dates from pre-Vindhyan times; and the supposed Vindhyan rocks of Jodhpur to the west of the Arvali, if really of contemporaneous age with the main area of Upper Vindhyans, may have been deposited in a second basin.

It is not possible, in the absence of fossils, to express any decided opinion as to whether the Upper Vindhyans are of marine or freshwater origin. The prevalence of sandstones, the subordinate character of the limestones, the approximate limitation to a defined, although extensive, tract, the want of fossils, and, considering the probability that the series was deposited in an inland basin, the absence of any deposits of salt or gypsum,—are all in favour of freshwater origin; but it cannot be said that these arguments are conclusive. The frequent occurrence of rippling on the shales and finer sandstones indicates that the rocks are shallow-water deposits. No contemporaneous igneous rocks are known.

The Vindhyans are the latest azoic rocks of the Peninsula. So far, there is no indication of any defined geological horizon. The complete severance between the Vindhyans and the Gondwánas, the next series in ascending order, prevents the deduction of any inference from the latter as to the age of the former. The only clue to the magnitude of the break is furnished by the relations between the Gondwánas and the azoic slates of the Sikkim Himalayas. The details will be found in Chapter XXV. The evidence is too uncertain to be accepted with much confidence; but, so far as it goes, it is in favour of the Vindhyans being classed as very ancient, and perhaps as pre-silurian.

Probable conditions of deposit.—From such data as have been hitherto afforded but little can be inferred as to the history of the Peninsula in pre-Vindhyan periods. The peculiarities exhibited by the various local groups of transition rocks are in favour of deposition in isolated areas, and consequently of a considerable proportion of the country having been above the sea; and there is even a greater probability, that India was a land area, or part of a land area, in Upper Vindhyan times than in the previous eras. The great break which succeeds the Vindhyan age may mark an extensive and prolonged period of terrestrial conditions. For any indication of the history of the country in early palæozoic times, we must leave the Peninsula, and turn to the Punjab and

the Himalayas. The oldest beds to the eastward, in Burma, are too little explored to afford information, and, so far as they are known, they present no marked distinction from the peninsular rocks; whilst the metamorphic and transition formations of the Assam hills are similar to those of Bengal. Along the western frontier, in the Punjab and Sind, no old beds are known; and proceeding to the northward, the first palæozoic rocks exposed at the surface within Indian limits are in the Salt Range of the Punjab.

Palæozoic rocks of Salt Range.—In this Salt Range there is a very remarkable and interesting phenomenon. At the eastern termination of the range almost all the older rocks consist of unfossiliferous sandstones, whilst to the westward marine rocks containing fossils prevail. The very oldest formation, however, is destitute of fossils throughout the range; and the most ancient form of life occurs near the eastern end of the hills. The idea, suggested by Dr. Waagen, that the Salt Range marks a portion of the limit of the ancient peninsular land, is highly probable; but the evidence of the replacement of marine formations to the westward by unfossiliferous sandstones, indicating freshwater or terrestrial conditions to the eastward, begins with the carboniferous period.

The oldest group of the Salt Range is a bed, at least 1,500 feet thick in places, of bright-red marl, with thick beds of rock-salt and gypsum. This is succeeded in ascending order by from 250 to 450 feet of deep purple sandstone, and then comes the lowest band containing recognisable fossils—a belt of black shale with calcareous layers. In the two lower groups only obscure and indistinct traces of fucoids and markings resembling annelid burrows have been detected; but in the shale Mr. Wynne obtained a small brachiopod closely resembling *Obolus*. This probably indicates marine conditions and a lower palæozoic horizon. Above the shale comes another unfossiliferous bed, the "magnesian sandstone," a pale-coloured sandy dolomite, about 200 feet thick. At the east end of the range this is succeeded by bright-red clays and flaggy sandstones, and then come upper mesozoic or tertiary rocks. Various changes take place in the series farther west, and it is by no means certain how far the formations at the two ends of the range represent each other; but to the westward the various unfossiliferous sandstones die out, and the salt marl is immediately overlaid by carboniferous limestone, with the typical fossils, *Productus*, *Spirifer*, &c. It is clear that there must be a great break in sequence between the salt marl and the carboniferous limestone; for several hundred feet of sandstones intervene between the two, where the limestone first makes its appearance in the

middle of the range; and the salt marl is in all probability of silurian age at the latest.

The red marl, with thick beds of salt and gypsum at the base of the section, can scarcely have been formed otherwise than in an inland basin: whether in partial or occasional communication with the sea or not, it is, of course, impossible to say. The interstratification of the *Obolus* band with the unfossiliferous sandstones very probably indicates alternation of marine and terrestrial conditions; and in upper palæozoic times the sea evidently occupied the region now forming the western portion of the range. But the fossils of the Salt Range carboniferous limestone are in many cases the same as those found in Europe, in America, and in Australia; and to the westward and northward, similar limestone, with the same shells, is found in the Sulemán range and in Kashmir, and far to the eastward, in the trans-Himalayan area; so that it is a reasonable inference, that the sea in which the carboniferous limestone of the Salt Range was deposited was part of the great ocean. At the same time if, as appears probable, some of the sandstones to the eastward are of contemporaneous origin with the upper palæozoic limestone of the Western Salt Range, the existence of a coast line is indicated, even if the sandstone beds be not of freshwater origin; for many conglomeratic bands occur.

Oldest rocks of Northern Punjab, Kashmir, &c.—Farther to the north in the Punjab, in the neighbourhood of Attock and of Abbottabad in Hazára, the oldest unaltered rocks are unfossiliferous slates, with some limestones, and occasional bands of basic volcanic rocks, perhaps contemporaneous. In Hazára, near the Indus, metamorphic rocks occur; but their relations to the slates are not determined with certainty, the one being possibly in part an altered form of the other. The carboniferous limestone has not been found in place in the extreme north of the Punjab; but some mesozoic beds overlying the Attock slates are related to Himalayan rocks of the same age; and farther to the eastward, in Northern Kashmir, and other parts of the North-West Himalayas, similar mesozoic rocks rest upon carboniferous limestone; and this last is succeeded in descending order by a great mass of slates, sandstones, quartzites, &c., resting, in turn, upon gneiss. In Kashmir itself and its neighbourhood no fossils have been found below the carboniferous formation; but farther to the southeastward, in Spiti, two fossiliferous bands, the Bhábeh and Muth beds of Stoliczka, have been detected, both probably of silurian age. Still farther east, too, in the north of Kumaun, silurian fossils have been discovered in considerable quantities. There is reason for believing that the Attock slates are a continuation to the westward of the slates of Lahúl,

Kishtwár, and Kashmir; that the latter are representatives of the silurian rocks of Spiti and Kumaun, and that the whole of these rocks are marine. Contemporaneous traps are associated with these silurian formations both in Spiti and Kashmir, and may in great part be of subaqueous origin; though the amygdaloidal eruptive rocks of the Kashmir valley rather resemble subaërial lava flows in some respects. On the whole, the probabilities are in favour of marine conditions having prevailed throughout the extreme north of the Punjab, Kashmir, and the neighbouring countries north of the Dhauladhár and main Himalayan range in lower palæozoic times.

Oldest rocks of Himalaya.—The formations in the Western Himalayan area of earlier age than silurian are quite unfossiliferous and much altered. They consist of gneissic rocks of two ages: the central gneiss of Stoliczka, and a newer series resting upon the older, and passing upwards into the silurian slates, which are shewn to be unconformable to the older gneiss by containing large quantities of fragments derived from it. Neither of these forms of gneiss affords any distinct clue to the conditions under which it was originally deposited; but the newer probably consists of altered marine beds.

It has already been intimated, that the marine palæozoic formations already noticed are found to lie north of the main Himalayan axis, the great range of crystalline rocks forming the snowy range north of Simla, and terminating apparently in the Dhauladhár. South of this range, resting upon the ancient gneiss in the neighbourhood of Simla, and elsewhere, is a series of schists, quartzites, sandstones, shales, limestones, &c., in which no fossils are known to have been found; some supposed discoveries of mesozoic and tertiary shells amongst these beds having too many elements of doubt to be recognised as authentic. These rocks are known in ascending order as the Infra-Blaini, Blaini, Infra-Król, and Król beds; and they have been supposed by various observers to represent the trans-Himalayan formations in different ways. The most conspicuous band is a massive limestone—the Król limestone of the Simla region. This rock has been traced for a considerable distance both eastward and westward, and was for some time by Dr. Stoliczka supposed to represent the triassic formation of Spiti; but a more probable representative has been recently indicated by Mr. Lydekker in the limestone of the Pir Panjál, believed on fair evidence to be of carboniferous age. If this conclusion be correct, the cis-Himalayan strata of Simla are probably, in part at least, altered palæozoic marine beds; although the absence of fossils, and the great petrological differences from the trans-Himalayan formations, have led to the suggestion, that the Blaini and Król rocks

belong to the peninsular type. No definite connexion with peninsular rocks can, however, be made out.

There is much obscurity attending the relations of the Blaini and Król rocks of the Lower Himalayas to the older gneiss; and in some places, instead of the slaty series resting upon the gneissic formation, the latter appears to overlie the former. There can be little doubt but that such an appearance is illusory, and due to disturbance of later date; in all probability, the Blaini and Król rocks, although of palæozoic age, are much newer than the gneiss, and they are certainly unconformable to it. There appears some reason for inferring that the palæozoic slates, sandstones, and limestones occupy hollows formed by denudation in the old gneissic rocks, and that subsequent pressure has produced the appearance of inversion. If this be a correct view, it is probable that the cis-Himalayan palæozoic rocks are in great part of freshwater origin, and that the present crystalline axis of the Western Himalayas approximately coincides with the shore of the ancient palæozoic continent, of which the Indian Peninsula formed a portion.

Passing eastward along the Himalayas, the whole of the country north of the snowy range is unknown; and it is only possible to infer, from a few marine fossils brought from various parts of Tibet, that there is a continuation in that direction of the Spiti and Kumaun rocks. Along the southern slopes of the Himalayas also, owing to political difficulties, scarcely anything is known of the geology. A possible representative of the Król group is found near Kathmándu in Nepál, and another may perhaps be traced in Bhútan; but the only formation of definite age in this direction is a peninsular rock, the Damúda, to which it will be necessary to refer presently. To the eastward, in Burma, the only fossiliferous palæozoic rock known is the carboniferous limestone of Tenasserim. Devonian rocks are said to have been found in Eastern Tibet.[1]

In the preceding brief survey of our present acquaintance with the azoic and palæozoic formations, it will be seen that, so far as the rocks are known, there is a remarkable divergence between the peninsular and extra-peninsular rocks: a difference so great as to lead to the conclusion, that very different conditions prevailed in the two areas. To this there may have been at first an exception in the case of Burma, where the oldest rocks have not been shewn to be distinct from those of the Peninsula; although, in the newer palæozoic carboniferous times, the sea evidently covered part of the Burmese area; whilst there is no trace of any marine carboniferous formation in the Indian Peninsula.

[1] Comptes Rendues, LVIII, p. 878:—Geol. Mag., I, 1864, p. 76.

At the same time, there is a well-marked distinction between cis-Himalayan and trans-Himalayan formations; the former differing less from the peninsular type than the latter do, and the latter being marine, whereas the former are, in part at least, freshwater. It will be seen that there is the same, or even a greater, contrast from the extra-peninsular formations shewn by the mesozoic and tertiary rocks of the Peninsula, to which it is now necessary to turn.

Gondwana system.—It has already been pointed out, that, in dealing with Indian rocks, it is impossible always to keep to the classification adopted for very different formations in a distant part of Europe. There is good reason for believing that the lowest Gondwána beds of the Peninsula may be of upper palæozoic age; but they are divided by a great break from the next older series, the Vindhyans, whilst they are intimately connected with the Upper Gondwána rocks, which are certainly mesozoic. In returning from the comparison of the extra-peninsular palæozoic rocks to the peninsular area, and in commencing the examination of the Indian mesozoic formations, it is necessary to commence with formations which may represent, in part at least, the upper palæozoic marine beds of the Punjab, the Himalayas, and Burma.

In the Gondwána system organic remains appear for the first time in the Peninsula. But even in these rocks no marine fossils are found in the lower sub-division, all the groups of which consist of sandstone and shale, in some cases with beds of coal, and appear to be of freshwater origin. From a consideration of all the facts known, the approximate age assigned to the Lower Gondwánas is permian and triassic, possibly a little older or a little newer, the evidence being by no means conclusive: the Upper Gondwánas are with more certainty classed as jurassic. The upper sub-division also consists chiefly of sandstones, occasionally associated with clays or marls; and in one instance the beds are interstratified with contemporaneous basaltic lava flows.

The area occupied by the beds of the Gondwána system, although very extensive, is mainly confined to the country between the Narbada and Sôn to the north and the Krishna to the south; and a very large portion of this region to the westward is occupied by newer beds. The only outliers in the Peninsula beyond the limits named are near the east coast, and to the westward in Kattywar, Cutch, and Jesalmir, and consist of Upper Gondwána beds alone; but Lower Gondwánas have been traced for some distance along the base of the Eastern Himalayas.

The Gondwána beds are distributed in large basins, some of which shew a remarkable coincidence with the existing river valleys; and it has hence been inferred that, as the beds are probably of fluviatile origin,

the river valleys of the present day are the same, or nearly the same, as those of the Gondwána period. This conclusion is, however, not admitted by all observers, and must be received with great caution; the distribution of the rocks, in some instances, being quite different from that of the existing drainage areas, and the agreement between the ancient Gondwána basins and the modern river system being perhaps due, where it exists, to the softness of the Gondwána rocks, and to their having in consequence been more easily worn away by rivers. It is a curious circumstance, that the lowest Gondwána beds are singularly constant in character throughout the whole extensive area in which they are found; whilst the difference between the rocks in the different basins is much greater in the higher members of the Lower Gondwána series, and becomes still more marked in the Upper Gondwánas. There are also more marks of local disturbance, sharp dips and faulting, in the Lower Gondwána rocks than in the upper; and it is clear that in some instances the Lower Gondwánas had been tilted and faulted before the Upper Gondwánas were deposited. It is consequently far from improbable that the present Gondwána basins date from Upper Gondwána, not from Lower Gondwána, times. In the Upper Gondwánas, too, there is evidence that the coast line of the Peninsula had begun to assume its present form; for in many places along the east coast, from near Cuttack to Trichinopoly, small patches of Upper Gondwána rocks are found, in several cases interstratified with marine beds, but yet distinctly, in part, shewn to be either of fluviatile, deltaic, or littoral origin, from the coarseness of the materials and the abundance of remains of land plants. In some places, too, as near Ellore, these Upper Gondwána beds of the east coast rest upon a denuded slope partly of gneissic and partly of Lower Gondwána rocks, having the appearance of a plane of marine denudation. Gondwána beds occur near the east coast farther still to the north, close to Cuttack, but no marine beds are associated; and to the north and north-east no marine jurassic rocks are known to exist. There is consequently no evidence whether the jurassic coast ran farther north in that direction; although, as will be seen, the sea extended much farther in that direction in cretaceous times. Again, to the westward, in Cutch, Upper Gondwána beds are found interstratified with marine rocks of upper jurassic age, and containing the same fossils as the beds on the east coast; the same Upper Gondwána rocks have been traced in Kattywar, and some, probably a little older, occur in the great desert near Jesalmir and Bálmir, where also marine jurassic beds are associated. Now, it is a remarkable fact, that this indication of the ancient coast line is entirely confined to the Upper Gondwána beds; Lower Gond-

wánas being only associated with the upper in a single instance, near Ellore, where the two are quite unconformable, and where the lower series appears to have been planed away, before the deposition of the upper, by the marine denudation to which the slope already mentioned is due. It is only reasonable to conclude, that important changes in the configuration of the country took place in the interval between the Upper and Lower Gondwána periods.

The most marked distinction between the Gondwána basins and the existing river drainage areas is found in the Sátpura region, where the Gondwána rocks form the watershed between the Narbada and Godávari, and do not descend into the main valley of either river; the Gondwána basin of the Godávari itself being quite distinct. In this instance, however, if there had been any coincidence in the former and present river areas, the resemblance could only be due to accident, or to the facilities afforded by the soft Gondwána formations for subaërial denudation, because the whole region in later mesozoic and early tertiary times was covered with a uniform sheet of basaltic lava flows, by which all the ancient features of the country must have been obliterated. It is out of this great sheet of igneous rock that the hills and valleys of Western and Central India have been carved in tertiary and recent times; and amongst the tracts thus exposed by denudation are the Gondwána regions of the Sátpura hills, and, in great part, of the Sôn, Upper Mahánadi and Godávari valleys. Indeed, the vast tracts of Gondwána rocks now exposed in these areas owe their preservation, in all probability, to the protection from denudation afforded by the overlying traps.

In part of Bengal a change in the configuration of the country through the eruption of igneous rocks took place at even an earlier period,—in the Upper Gondwána epoch itself. In the Rájmahál hills, resting unconformably upon the lower Gondwána Damúdas, themselves by no means the uppermost members of the lower sub-division, there is found a band of Upper Gondwána sandstone; and over this again, with slight local unconformity, a great thickness of basaltic lava flows, with interstratified sedimentary beds containing plants. It is not probable that these lava flows were restricted to their present area; and, from the abundance of trap dykes in those Gondwána basins of the Damúda valley which are in the neighbourhood of the Rájmahál hills, and the gradual diminution in the size and number of such dykes as the distance from the hills increases, it is highly probable that part of the Damúda valley was at one time also covered by horizontal traps. Whether this was the case or not, depends upon whether the highest Gondwána beds, referred to the Mahádevas, in the Damúda valley, are older than the

Rájmahál lava flows or newer. If the former, the ground may have been covered with basalt; if the latter, this can scarcely have been the case, as a layer of basalt would have been preserved below the Mahádeva outliers. In favour of the newer age of the Mahádevas, it should be noted, that no trap dyke has been found in them; although such intrusions occur in all Lower Gondwána beds.

So great an outburst of igneous rocks was probably preceded and accompanied by very important changes in the elevation of the neighbouring country; and it is evident that all these changes, and the alteration of the surface by the outburst of traps, must have produced great modifications in the form of the river valleys. Indeed, the manner in which several small Lower Gondwána basins, now isolated, but shewing, by the disturbance they have undergone, that their present isolation is due to denudation, are scattered over the country to the west of the Rájmahál hills, indicates the probability that all were once parts of an extensive river valley; and the complete absence of Upper Gondwána rocks in all these small basins may very possibly be due to the breaking up of the river valley in the interim between the Lower and Upper Gondwána periods.

On the eastern side of the Rájmahál hills there is also a possibility that the traps extended across the area now occupied by the upper part of the Ganges delta, and were connected with the stratified traps found north of Sylhet. This is no more than a suggestion; but still the Lower Gondwána land, in all probability, extended to the north-east, as is shewn by the occurrence of Damúda rocks north of Assam; and it is quite possible that the Upper Gondwána terrestrial area may have been continued in the same direction. At the same time, the Sylhet traps may, even if contemporaneous with those of Rájmahál, belong to a different volcanic centre. But the Rájmahál traps shew no signs of thinning out to the eastward, where they disappear beneath the alluvial deposits of the Ganges valley; and it is only reasonable to suppose that they extend for a considerable distance beneath the alluvial covering. Thus, even in Upper Gondwána times, not only is there no reason for supposing that the greatest river valley of India existed, but there is some indication that it had not been formed. As will be shewn presently, there is a probability that the depression of the Gangetic plain, to the eastward at all events, is of tertiary origin.

The very marked difference between the Upper and Lower Gondwána floras, and the connexion that exists between the plants found in the different groups of each of the two major sub-divisions of the system, also point to a break of time of considerable magnitude between the two series.

Physical geography of Gondwana period.—We can thus form some slight conception of the physical geography of India in the Upper Gondwána period. The sea then, as now, occupied the Bay of Bengal, and a portion, at all events, of the Arabian Sea; and large rivers traversed the land then, as now, though not in precisely the same courses. The general form of the southern part of the Peninsula may have agreed more nearly with the present contour than the northern; for the sea occupied the Indian desert and portions of the Punjab and Himalayas. There is not the same clue to the form of the land in the Lower Gondwána period; and all that can be said with certainty is, that the northern part of the Peninsula was a terrestrial area, traversed by great rivers. To the north-east the occurrence of Damúda beds at the base of the Himalayas, in Sikkim and Bhután, may intimate an extension of land in that direction, and a possible connexion with the Chinese area, in which plants allied to those of the Damúda are known to have been found. Such faint indications of the relations between the Damúdas and other Himalayan beds as can be learned from the very obscure mode in which the Gondwána rocks occur in the Eastern Himalayas will be found in Chapter XXV. All the data hitherto ascertained are too imperfect for any conclusions as to age to be based upon them.

Two other subjects of interest remain for notice: the connection with other countries shewn by the fossil flora and fauna of the Gondwána period; and the evidence of climate.

Relations of Gondwana flora and fauna.—The plants of the Lower Gondwánas consist of acrogens and gymnogens; the former, represented by *Equisetaceæ* and ferns, being far more abundant both in species and individuals than the latter, consisting of cycads and conifers. In the Upper Gondwánas the same classes are found; but the proportion is reversed, the conifers, and especially the cycads, being more numerous than the ferns, whilst *Equisetaceæ* are barely represented. The fauna is singularly poor, no animal remains being found in most of the beds; and even plants are scarce in many of the groups. The only formations in which plant remains occur in abundance are the Karharbári, Damúda, and Rájmahál; and even in these the number of species is comparatively far from great.

There are three distinct floras in the Lower Gondwána series: (1) the Tálchir and Karharbári, (2) the Damúda, and (3) the Panchet; and two, besides some intermediate groups, in the Upper Gondwánas: (1) the Rájmahál, and (2) the Jabalpur and Cutch flora. The Tálchir and Karharbári flora has a marked affinity to that of the European Trias, and especially to the Bunter, the lowest sub-division of the Trias; but there is an equally

close connexion with the upper palæozoic (carboniferous) flora in Australia This resemblance to the Australian carbonifetous flora is very much more marked in the next Gondwána group, the Damúda, a considerable proportion of the forms being closely allied, and some being identical; and there is also a close connexion between the Damúda plants and those found in the Karoo series of Southern Africa. Some of the same plants are also found in China; but the details are as yet imperfectly known. On the other hand, the affinity between the Damúda flora and that of any lower mesozoic or palæozoic group in Europe is comparatively small. Some Damuda plants are certainly allied to species found in carboniferous, permian, triassic, and jurassic beds, and perhaps the most marked connexion is with the lower oolites; indeed, the resemblance of a few plants in this case led to both the Damúda beds and the Australian being for a long time classed as jurassic. As will be seen presently, however, there is a very much closer alliance between the plants of the lower oolites and those of the uppermost Gondwána flora; and the latter is divided by an immense thickness of beds and several successive floras from the Damúdas.

Only vestiges of animal remains have been found in the Karharbári and in the typical Damúda beds; but in the Mángli beds, belonging in all probability to the Upper Damúdas, a labyrinthodont skull has been obtained, closely related to a type found, like some Damúda plants, in the South African Karoo beds. In the Panchet group, above the Damúdas, remains of dicynodont reptiles occur, also evincing a connexion with the same South African beds. Two labyrinthodonts, also found in the Panchet beds, are most nearly allied to European triassic forms. Of the four species of Panchet plants known, two are European rhætic species, and the others are allied to rhætic forms, one being, however, nearer to a lower triassic type.

Of the Upper Gondwána floras, the Rájmahál has but little in common with any European assemblage of plants; but it, like the Panchet, is most nearly affined to the rhætic. As between the Rájmaháls and Panchets there is the greatest break, both in palæontology and geological sequence, in the whole Gondwána system, the circumstance, that the flora of both is related to that of the same minor sub-division of the European series, shews that too much weight must not be attached to similar cases of affinity in determining age. The Cutch and Jabalpur flora again contains several plants, apparently identical with forms found in lower oolitic (middle jurassic) beds in Europe, the relations, as already stated, being by far the most intimate of any between Gondwána and European fossil floras; but the Cutch beds overlie uppermost jurassic

marine strata, and underlie upper neocomian beds, so that if marine fossils be accepted as a criterion of age, the horizon of these Cutch strata with lower oolitic plants must be very nearly that of the European Wealden. In one of the Upper Gondwána groups, that of Kota-Maleri, found in the Southern Central Provinces, and supposed, on the evidence of a very poor flora, to be intermediate in age between Rájmahál and Jabalpur, a considerable number of ganoid fishes, with distinctly liassic affinities, belonging to the genera *Lepidotus*, *Tetragonolepis*, and *Dapedius*, are found in a bed interstratified with rocks containing teeth of *Ceratodus*, and remains of two reptiles, *Hyperodapedon* and *Parasuchus*—all characteristic triassic forms. The contradictions as to age of the Gondwána fauna and flora are thus very great, so long as these beds are compared with the European sequence. As a general rule, in the Upper Gondwánas all the forms appear to have lived at a later period than in Europe; but in the Lower Gondwánas the reverse is the case. The Rájmahál beds are very possibly not quite so old as rhætic. There is much probability that the Kota-Maleri group is newer than liassic, and it is certainly of later age than the trias; the Umia group of Cutch is clearly posterior in date to the lower oolite, whilst, on the other hand, amongst the Lower Gondwána formations, the Karharbáris are probably older than triassic; the Damúdas are certainly of pre-jurassic age, and the Panchets may very possibly, although triassic, represent a somewhat earlier period than that of the rhætic group.

It would of course be equally unsafe to insist upon the affinities of the Karharbári, Damúda, and Rájmahál floras, and of the Mángli and Panchet faunas, with those of various beds in South Africa and Australia, as proving contemporaneous age. But the very marked affinities between the different terrestrial forms of plants and animals in the rocks of these distant regions may be fairly assumed to shew that there was at times, if not continuously, land connexion between the two countries. In the Lower Gondwánas the relations with the Australian forms of life are stronger than with the European. Whilst the Damúda flora exhibits the most marked relationship to that found in beds intercalated with marine carboniferous rocks, or conformably overlying them, in Australia, neither the Australian nor the Damúda plants have any resemblance to those found in the coal-measures of Europe; although the latter occur in beds having precisely the same relations to the carboniferous mountain limestone as the Australian rocks have to the marine beds with mountain limestone fossils. It is reasonable to infer that at this period, or soon after, India was united with Australia by land, but not with Europe, and that the latter connexion took place later. Hence the occurrence of such Lower Gondwána types as are found in European beds in rocks of

later date in the last-named area: for instance, the genus *Phyllotheca*, found in the carboniferous beds of Australia and the Damúdas of India, but not in any formation older than jurassic in Europe. It is not improbable that the Lower Gondwánas of India are of intermediate age between the carboniferous of Australia and the trias of Europe.

Above the Lower Gondwánas the evidence of connexion with Australia is faint; and where any exists, it is perhaps, on the whole, in favour of a passage from India towards Australia. Thus the genus *Ceratodus* of the Indian Upper Gondwánas is represented by living freshwater fishes in Australia; and *Hyperodapedon* is most nearly related among recent lacertians to the New Zealand *Hatteria*. Such affinities, however, are of minor moment. In the case of Africa, the land connexion appears to have been more permanent, and it may have existed continuously to tertiary times. Some evidence on this point will be mentioned hereafter.

Some of the plants common to the Cutch or Jabalpur beds and the lower oolitic or middle jurassic rocks of Europe have also been found in parts of Eastern Europe and Western and Northern Asia; so that there is abundant evidence of this flora having been widely diffused in the northern hemisphere. Unfortunately the age of the rocks containing the plants appears in the majority of cases to have been inferred from the flora; and as this has been shewn to be insufficient evidence in India, it is impossible to tell whether the rocks at the various localities in South-Eastern Russia, the Caucasus, Northern Persia, Siberia, Northern China, and Japan, at which plants resembling those of the lower oolites have been found, are of contemporaneous origin; or whether they are intermediate in age between the middle jurassic beds of Western Europe and the upper jurassics or Wealden of Western India. It is fair to infer that the countries were connected by land during a portion of the intervening period; but it is quite uncertain how far the union was permanent, or to tell whether it still existed in upper jurassic times. It appears probable that the sea extended to the westward far north of Cutch; but there are some remarkable differences between the jurassic rocks of Cutch and those of the Himalayas; and these differences may have been due to a land barrier between the two regions.

Climate of Gondwana epoch.—The climatological evidence contained in the Gondwána rocks is very curious; and although it cannot be said to prove an epoch of low temperature, it certainly suggests it. In the Tálchir formation, almost wherever that extensively developed group is exposed, fragments of metamorphic, transition, or Vindhyan rocks are found imbedded. These fragments are always rounded, often of large size (many having been measured 6 feet in diameter, and some are pro-

bably larger), and in many cases imbedded in the finest silt. It is difficult to understand how such large blocks can have been transported and deposited in a fine mud without the agency of ice: roots of trees are out of the question where the occurrence is on so large a scale. In one instance, moreover, some of the blocks were found to be polished and striated, and the underlying Vindhyan rocks were similarly marked. The appearances are not such as would be produced by glaciers; and it appears more probable that if ice transported the blocks, it was in the fluviatile form known as ground ice. It was at first suggested that this might be the case without any change in the temperature, as the Talchir formation might have been deposited on a plateau sufficiently lofty for ground ice to be formed. But the additional evidence since obtained of similar deposits, apparently of glacial origin, in South Africa, in beds precisely corresponding to the Talchirs in position, the likelihood that the Permian breccias of England are also glacial, the poverty of the Permian fauna, and the great break in forms of life at the close of the palæozoic period, together with the additional astronomical data in favour of variation in the sun's heat—all combine to suggest the possibility of recurrent epochs of diminished temperature having taken place at intervals in the earth's history, and of one of these intervals having coincided with the Permian epoch. This might perhaps also explain the migration of Australian and African plants to the tropics, and the subsequent dissemination of these same plants in the temperate regions of Europe and Asia, as the earth's temperature increased again. There is nothing in the Lower Gondwána flora to indicate tropical affinities: the flora, as already noted, is poor, and the ferns might as well have inhabited a damp temperate climate as a tropical one; whilst the beds containing the Talchir boulders are singularly devoid of life, either vegetable or animal.

It should here be noticed that two cases of large boulders imbedded in a fine matrix are known in India amongst earlier rocks, and one at least in a later formation. One of these was in some transition beds, of unknown relations,[1] resting upon Maláni volcanic rocks near Pokran, between Jodhpur and Jesalmir, in Rájpútána. Here also a striation of the underlying formation was observed. The second case is in the Himalayas of Pángi, south-east of Kashmir. Here the old slates, supposed to be silurian, contain boulders in great numbers. The third instance was in the Salt Range, where blocks of great size are imbedded in a clay supposed to be of upper cretaceous age; and one of the boulders was found to be polished and striated in a very characteristic manner on three different faces.

[1] Rec. G. S. I., X, p 13. The notice of this boulder bed has been omitted in Chapter II of this work.

Another method of accounting for the difference of temperature in past times is that noticed a few pages back, when the absence of life in the Vindhyan rocks was mentioned—a possible change in the direction of the earth's axis. Whether such a change can have taken place is a question that may be left to astronomers and mathematicians, and that appears as yet to be by no means decided. So far as the climate of India in past times is concerned, granting, as appears probable, that a lower temperature prevailed in certain past epochs, either a secular refrigeration or a change in the earth's axis would equally account for the deficiency of heat. It is extremely doubtful, however, whether any change in the relative positions of the earth's surface could satisfactorily account for the recent glacial epoch, of which, as will be seen, the effects were probably felt in India; and if a cool temperature prevailed in the Permian period, it is highly probable that it was due to the same cause as in pleistocene times.

Jurassic marine rocks.—The marine zones associated with the Upper Gondwána beds of the east coast have not, with one exception, been accurately determined; but few characteristic forms of fossils occur, and the majority of the species found have not been determined. The exception is the highest marine bed known, in which forms of *Trigonia*, *T. ventricosa*, and *T. smeei*, have been found, characteristic of the higher or Umia beds in Cutch. The Cutch jurassics afford a very complete representation of all the European jurassic beds above the inferior oolite; the Bath, Kelloway, Oxford, Kimmeridge, and Portland faunas being more or less clearly distinguished. No equally full sequence of marine jurassic beds is known to the northward in the extra-peninsular area, but the upper jurassics are, as will presently be shewn, represented in the Punjab and the Himalayas. North of Cutch also, in several parts of the desert country between the Indus and the Arvali mountains, jurassic rocks are found, the best known being, perhaps, some near Jesalmir, of Oxford or Kelloway age: with these, as already mentioned, are associated beds apparently of freshwater or littoral origin, and containing obscure remains of terrestrial plants and fossil wood. It is probable that the jurassic coast line of the Peninsula ran northward from Cutch through Western Rájputána to the Salt Range of the Punjab, where also marine jurassic rocks containing plant remains are found, but are restricted, like carboniferous and triassic marine formations, to the western part of the range.

The highest jurassic group in Cutch, that of Umia, contains at the base a marine fauna, with several species of mollusca common to the Portland zone of the European oolites, and also some forms, amongst

which two *Trigoniæ*, *T. ventricosa* and *T. vau*, are conspicuous, characteristic of certain very high jurassic beds in Southern Africa. The plants identical with forms found in the inferior oolite beds of Europe occur at a rather higher horizon; but there is some intercalation of marine fossils above the plant beds. Above the whole, whether conformably or not is uncertain, is a thin band with upper neocomian *Cephalopoda*; and this is succeeded by Deccan trap, the last-named formation being unconformable to the underlying beds.

Cretaceous marine beds.—No association of upper cretaceous beds with the marine jurassic rocks has hitherto been clearly traced on the eastern shores of the Peninsula; although some fossils, which may belong to a very high cretaceous horizon, occur at the base of the traps near Rájámahendri (Rajamundry) and Ellore, overlying beds, believed to be identical with those containing *Trigonia smeei* and *T. ventricosa* a little farther to the north-east; and some cretaceous mollusca have been brought from Sripermatur, west of Madras, where, however, the relations of the rocks containing them to the beds with marine remains in the Sripermatur Upper Gondwána beds are very obscure. By far the most important cretaceous deposits of India are those of the neighbourhood of Pondicherry and Trichinopoly, where a series of marine fossiliferous strata, classed in ascending order as the Utatúr, Trichinopoly, and Arialúr groups, corresponds in age to the European cretaceous beds, from Upper Greensand or Cenomanian to Upper Chalk or Senonian inclusive. The uppermost strata of the Arialúr group may possibly represent a still higher horizon; but they have not been definitely distinguished. The lowest group or Utatúr rests in places, with slight unconformity, on Upper Gondwána beds, apparently, to judge by the flora, of an age intermediate between Rájmahál and Jabalpur, and elsewhere upon the gneiss: at the base of the Utatúr group there is frequently a great coral reef. Great unconformity exists between the Utatúr and Trichinopoly groups, and some may also occur between the Trichinopoly and Arialúr; but it is chiefly shewn in the latter case by overlap.

All the groups are in part or wholly of littoral origin; none appear to be deep-water deposits. Fossil wood is found abundantly in the two higher groups; and there is evidence of a tract of land north of Trichinopoly having been elevated above the sea and brought under the influence of denudation in the interval between the Utatúr and Trichinopoly groups. Everything combines to suggest that the eastern coast line of Southern India in upper cretaceous times was but a few miles farther west than it is now, and that the general direction was the same. The occurrence of marine beds at the base of the traps near

Rájámahendri and Ellore, although the geological horizon is not quite certain, and may be later than that of the Arialúr beds, tends to indicate the continuance of the same coast line. Again, in the Khási and Gáro hills, and throughout a great part of the Assam range, marine cretaceous beds occur, containing in large numbers the same fossils as the rocks of Trichinopoly, and probably deposited in the same sea, and very possibly on the same line of coast. There is, however, a break between Ellore and the Gáro hills; and there is not the slightest indication of marine conditions in cretaceous times in the Ganges valley. Marine cretaceous beds occur also in Burma; but only one fossil, an ammonite (a Trichinopoly species) has hitherto been procured from them.

Similar fossils are not found elsewhere in India; but in South Africa there is again, as in the Gondwána and marine jurassic beds, a singularly close connexion with the rocks of Southern India. In some marine cretaceous strata of Natal, the majority of the fossils found are identical with those of the Trichinopoly formations. As the fossils are chiefly shallow-water and littoral forms, it appears a probable conclusion, that a line of coast extended in cretaceous times from India to South Africa.

Distribution of cretaceous land.—From the remains found in another part of India, some farther indication is afforded of the distribution of land in the upper cretaceous period. In the Narbada valley here and there, from Barwaha (Barwai) to the neighbourhood of Baroda, some poorly fossiliferous sandstones and limestones are found at the base of the Deccan traps; and near Bágh, a band containing a rather better series of fossils has been discovered in a bed associated with these sandstones. The fossils are characteristically of Upper Greensand (Cenomanian) age, the same as the Utatúr group; but only one species out of eight or nine well-identified forms from the Bágh beds is common to the rocks of Southern India, and this species, *Pecten* (*Vola*) *quinquecostatus*, is one of the most widely spread of cretaceous fossils, and is represented by distinct varieties in the Narbada valley and near Trichinopoly. But whilst there is thus a wide difference between the fossils of the Bágh beds and those of the probably contemporaneous strata in Southern India, there is precisely the same resemblance between the Bágh fauna and that of certain beds of the European Upper Greensand, as there is between the South Indian cretaceous deposits and those of South Africa: the Bágh fauna being also found represented in Southern Arabia. It has already been shewn that a coast line probably extended from India to Southern Africa, and it does not appear an unreasonable inference that this coast may have been the southern shore of a land barrier separating the seas

of Europe, Arabia, and Western India from those in which the deposits of the Assam hills, Trichinopoly, and Natal were accumulated. There was thus very probably in cretaceous times the same union with Africa as already indicated in the later palæozoic and older mesozoic period, and the same coast line along the eastern shore of the Indian Peninsula as in the jurassic epoch, but perhaps extending much farther to the north-east. In cretaceous times, as in earlier mesozoic periods, there is no indication of any deposits having taken place in the Ganges valley; and the absence of any mesozoic beds between the tertiaries of the Sub-Himalayas and the ancient rocks of the mountains is rather opposed to any large accumulation of strata, either subaërial or aqueous, having been formed, in the intervening epochs, within the area of the Gangetic plain.

The number of species common to the whole cretaceous fauna of Southern India and that of Europe is 16 per cent.; but the proportion varies in the different groups, being greatest in the Utatúr, 18 per cent., and least in the Arialúr, 12 per cent.; those species only being taken into calculation which are in India peculiar to each group. In the Trichinopoly group the percentage of European species is 15. The gradual diminution in the number of common species may mark the effects of a long-continued period during which the European seas were only in indirect communication, probably by a circuitous route, with those of India; the direct communication having been cut off after the latest jurassic times, when the connexion between the areas was shewn by the same species (*Trigonia ventricosa*, &c.) occurring on both coasts of India. The resemblance of the South Indian to the European cretaceous fauna is greatest in *Cephalopoda*, *Brachiopoda*, and *Echinodermata*, and is much less marked in *Gasteropoda*, *Lamellibranchiata*, *Bryozoa*, and corals. The representation of zones in Europe by the corresponding sub-divisions in India is, however, much less close than in the jurassic rocks of Cutch—a circumstance which also tends to indicate less direct communication between the seas. In the *Cephalopoda*, on which alone the comparison of the Cutch jurassics is founded, this irregularity is especially marked; Neocomian species being found throughout the South Indian upper cretaceous series, and the whole facies of the Utatúr *Cephalopoda*, amongst which no less than 25 per cent. are common to European deposits, agreeing better with the Gault than with the Upper Greensand fauna. The Utatúr group, it should be added, contains no less than 109 out of the 146 species of *Cephalopoda* found in the South Indian cretaceous deposits. Some South Indian cretaceous forms, too, are allied to European jurassic types; and three species belong to a section of *Ammonites* not found in

Europe in higher beds than the trias. Again, amongst the *Gasteropoda*, and especially in the upper or Arialúr group, a large number of tertiary and recent genera are represented.

Deccan traps.—Whilst the upper cretaceous beds were being deposited on the south-eastern coast of India, the volcanic outbursts of the Deccan traps must in all probability have commenced. These rocks form one of the grandest masses of bedded traps to be found in the world, and present several very interesting problems. The Deccan traps consist of a great series of basaltic lava flows, for the most part assuming the form of basalt; all either nearly horizontal, or presenting the appearance of having been so originally. They possess a vertical thickness of between 4,000 and 5,000 feet, in some of the Sahyádri scarps, and probably where thickest amount to 6,000 feet at least; and they cover an area roughly estimated at 200,000 square miles, and in all probability originally very much greater. These basalts thin out towards the extremity of the area, but they are traced from Sind to Chutia Nágpúr, and from Belgaum to north of Goona, or throughout 16 degrees of longitude and 9½ of latitude.

The absolute geological date of these igneous eruptions is difficult to fix, and they may have continued to be poured out during a long period. It has been suggested by some geologists that the Rájmahál traps of the Upper Gondwána period and the Deccan traps are portions of one continuous series of outbursts. This is one of those suggestions which are difficult of proof or disproof for want of evidence as to the precise geological horizon of the uppermost traps in the Rájmahál hills; but there is no known connexion between the two series of lava flows. Each is limited to a definite and separate area; for there is no reason to suppose that the Deccan traps ever extended beyond the western part of Chutia Nágpúr, whilst the most western dykes referable to the Rájmahál period are 100 miles farther east. It is not probable that the beds containing the Rájmahál fossil flora can be much newer than middle jurassic, whilst the oldest of the Deccan traps are clearly not older than upper cretaceous; and if the outbursts are supposed to be continuous, it must be inferred that the 2,000 feet of Rájmahál traps represent the accumulations of a period extending from jurassic to upper cretaceous, whilst the whole 6,000 feet or more of Deccan traps were poured out between upper cretaceous and lower eocene times. If the Sylhet traps are really contemporaneous with the Rájmahál, as is by no means improbable, continuity between the Rájmahál and Deccan trap periods is out of the question; for the Sylhet lava flows are overlain unconformably by cretaceous rocks of about the same age (Cenomanian) as those underlying the oldest Deccan

traps; but it is not quite certain that the Sylhet trap is of the same age as the Rájmahál; and even if the two belong to the same period, the uppermost Rájmahál lava flows might be of later date than those in the same relative position in Sylhet.

There is but little petrological distinction between the traps of Rájmahál and those of the Deccan; both consist chiefly of basalts, both are composed of nearly horizontal beds, and both, as will be shewn presently, are of subaërial origin; but in the absence of any direct evidence, it is premature to suggest that there is any connexion between the two formations, or to class them as portions of one great igneous series.

The oldest of the Deccan traps are slightly unconformable to the cretaceous (Cenomanian) rocks of Bágh, whilst middle eocene beds rest with complete unconformity upon the denuded surface of the upper trap beds in Guzerat; and in Sind one thin band of trap, evidently representative of part of the Deccan series, is intercalated between very high cretaceous and very low eocene beds; whilst another band of trap, also apparently of contemporaneous origin, occurs interstratified with upper cretaceous beds several hundred feet below the upper band. The older traps are consequently classed as upper cretaceous; but it is far from improbable that the uppermost beds may be of the earliest eocene age, and that the traps may represent the whole intervening period between cretaceous and tertiary.

The Deccan traps have been very generally considered tertiary, chiefly on the evidence of the freshwater shells in some of the intertrappean beds; but these shells, as will be shewn in subsequent pages, have not been quite correctly determined, and the stratigraphical evidence is intrinsically of more importance, besides being better established.

In the Narbada valley, where the Deccan traps rest upon the marine cretaceous beds of Bágh, there is a peculiarity about the very slight unconformity between the two formations, characteristic of subaërial denudation; and there appears no reasonable doubt that the Bágh beds had been elevated above the sea before they were covered by the lava flows of the Deccan period. Elsewhere at the base of the traps either freshwater beds, known as Lametas, are found, or the basalt rests upon a worn surface, evidently terrestrial, of metamorphic, transition, or Vindhyan rocks. The Lametas are a thin band, closely resembling the Bágh beds in mineral character, and possibly a freshwater representative of them. With the lowest traps of Central India, almost all round the outer limit of the trap area from Cutch through Rájputána and the Central Provinces to the Southern Mahratta Country, freshwater beds, apparently of lacustrine origin, are interstratified; and in these beds numerous freshwater mollusca

and remains of terrestrial plants, with a few insects, small crustacea, and fish, are found. In some few places coarser deposits, evidently transported by rivers, and containing rounded fragments derived from the underlying traps themselves, as well as from older rocks, are met with. All these deposits clearly prove that the lower traps were poured out on a land surface; and amongst the very highest lava flows of Bombay, 6,000 feet or more above the horizon of the Central Indian beds, freshwater deposits are again found, also teeming with life, both vegetable and animal, and affording evidence of terrestrial conditions. There are also found, in many parts of the trap area, thick beds of volcanic breccia, evidently of subaërial formation; for they want the stratified arrangement characteristic of subaqueous deposits. A few laminated ash-beds may have accumulated in lakes.

Despite the fact that the uppermost and lowermost beds are thus demonstrated to be subaërial, that many intermediate layers are also proved not to be of subaqueous origin, and that there is no structural difference between the beds shewn to be subaërial and the remainder of the series, it is still contended by some geologists that the Deccan traps must be submarine. This view was originally advanced before the data now ascertained were known; but the idea has not been entirely abandoned, even since it has been proved that a part at least of the lava flows must have been poured out on a land surface. The great distinction between all such horizontal bedded traps as those of the Deccan and the lava flows of modern volcanoes, and the enormous distance to which the trap flows must have been extended from the point of eruption, are characters not yet explained; but a favourite theory with some geologists, that such flows must have been submarine, because a lava flow would preserve its heat and fluidity longer under the pressure of a large volume of water than in the air, is not only unproved, but is opposed to the known properties of water. Moreover, submarine volcanic rocks are common in the older formations, and are very different in character from such rocks as the Deccan traps. All such subaqueous accumulations are interstratified with ordinary sediment, and so closely intermixed, that it is often difficult to tell whether they are really of igneous origin or not. Such are the trappoid beds of the Indian transition rocks. Now, in no single instance have rocks of this kind been detected in the Deccan trap series; on the other hand, the structure of the beds from top to bottom is that of ordinary subaërial lava flows. It may fairly be concluded that all such bedded traps as those of the Deccan and the Rájmahál hills are of subaërial origin.

Although the Deccan traps occasionally overlie or underlie marine deposits, there is almost always distinct unconformity between the two;

and there are but two localities, in very distant parts of India, where any interstratification of marine beds with igneous rocks has been detected. These cases of interstratification are, however, the sole clue afforded to the outline of the Indian continent in the Deccan trap period. The one has been already noticed as taking place in Sind; the other is at Rájámahendri. In both instances the trap is probably littoral, if not truly subaërial; in Sind, coarse beds, conglomerates, and sandstones are associated with the lower band of trap, whilst immediately over the upper layer, sandstones, apparently of freshwater, and probably of fluviatile origin, are found. Near Rájámahendri the bottom flow of basalt rests upon a marine stratum, and is overlain by a band containing estuarine fossils, followed by a second lava flow. The latter locality may intimate a continuance of the general line of coast that has been shewn to have existed in upper jurassic and cretaceous times, and that remains to the present day.

The Rájámahendri traps may possibly be part of a distinct outburst, as no lava flows are preserved in any portion of the interval, 210 miles in length, between Rájámahendri and the main trap area in the Godávari valley. In all probability, the limit of the trap outliers in Rájputána, the Vindhyan table-land, Chutia Nágpúr, and the Southern Mahratta Country nearly corresponds with the original boundary of the region covered with igneous rocks; for just beyond the limit laterite is found in many places resting directly on the older rocks; and the laterite appears, as will presently be seen, to be of but little later date than the highest traps. But along the Bombay coast the traps disappear beneath the sea, where they are at their greatest development; and, in consequence of their westwardly dip, the rocks seen on the coast are the highest known. How far the igneous rocks of the Deccan period extend in this direction, it is impossible to say, but probably for a considerable distance; for some of the great centres of eruption, to judge by the prevalence of dykes and similar intrusions, were in the neighbourhood of the west coast. It is probable also that the land in the Deccan trap period extended for a long distance to the westward.

Another circumstance, tending to indicate that the approximate limit of the area covered by the traps in India is shewn by the outliers, is, that throughout the circuit of the igneous rocks, from Rájputána, *viâ* Chutia Nágpúr, to the neighbourhood of Belgaum, trap dykes are rare or wanting; whilst in parts of the Narbada valley, in the Konkan north of Bombay, in Guzerat and Cutch, dykes and other intrusions abound. Many of these intrusive masses are of large dimensions, sometimes miles in diameter; and they doubtless fill the channels through which the eruptive rocks reached the surface. It is probable that the Deccan

traps flowed from vents without the formation of volcanic cones, as no traces of the inclined beds of such cones have been found; and the distinction may have been due to the greater fluidity and larger mass of ejected lava, and to its consequently increased power of transporting all the materials brought to the surface by igneous agency to a much greater distance from the point of emission.

High-level laterite.—It is evident that the close of the volcanic outbursts left all the surface of Western India a huge plain of basaltic rock, the plain which later denudation has carved into the hills and valleys of the Peninsula. The only formation superposed upon the basalt throughout the greater part of the area, with the exception of gravels and clays of late tertiary or subrecent date, is the high-level laterite, or iron clay, a ferruginous and argillaceous rock, from 30 or 40 to 200 feet thick, capping the summit of many of the highest trap plateaus, and also occurring on other rocks, beyond the limits of the trap area, in such a manner as to shew that the caps now remaining are merely isolated fragments of a bed once far more extensive. This bed probably covered a large portion of the trap area and the neighbouring regions, and perhaps extended throughout the greater portion of Peninsular India. Nor is this all. In the nummulitic beds of Guzerat, Cutch, Sind, and the Salt Range of the Punjab, and in the Subáthu beds of the Sub-Himalayas, all of middle eocene age, there are found one or more beds of ferruginous rocks absolutely undistinguishable from laterite, and probably, from their wide extent, of contemporaneous origin.

In many places the laterite bed passes into the uppermost traps, and hence it has been very naturally inferred, that laterite is merely an altered form of the basaltic rock itself; but it appears most probable that decomposed basalt, when iron peroxide is added, forms laterite, and that consequently passage from the one into the other is natural; but that the high-level laterite bed is really throughout of detrital origin, as it is proved to be in places by containing pebbles and sand. It probably consists of altered volcanic detritus, perhaps of scoriæ and lapilli; the excess of iron being either due to the ferruginous nature of the volcanic outbursts, or to a process of washing by which the lighter, less ferruginous matters were carried farther away from the original source of the materials, and formed deposits less easily consolidated, and, in consequence, more easily destroyed by denuding agencies. Other laterite formations, deposited after much denudation of the traps had taken place, and found at low levels in various parts of India, may have been derived, in some cases at least, from materials provided by the denudation of the high-level form.

Tertiary coasts of Peninsula.—With the high-level laterite the sequence of older rocks in the peninsular area of India may be considered to close, late tertiary and recent deposits alone remaining, except in a few places on the coast. It will now be necessary to return to the extra-peninsular areas, and to see what was their history in mesozoic and early tertiary times, so far as a record is preserved by the rocks, whilst the Peninsula, as has been shewn, was a land area, as it is now. It should be first stated that the tertiary rocks around the coasts of the Peninsula afford but a faint indication of the distribution of land and sea in tertiary times. No marine beds of later date than cretaceous are known on the east coast, and the only tertiary beds are the Cuddalore sandstones of uncertain date and origin; whilst on the west coast the sea certainly covered a portion of Guzerat in eocene and miocene times, the coast lines being perhaps not very different from what they are now, although the sea extended some distance in what is now an inland direction. To the south, in Travancore, for the first time in geological history, we find that a marine deposit was formed in the miocene age; and we may perhaps infer that the southern portion of the western coast then first assumed something resembling its present outline. When treating the probable inferences to be drawn from the Indian fauna as to the former connexion between India and other countries, it will be seen that India may have been directly connected with Africa till the middle of the tertiary period.

Extra-peninsular mesozoic rocks.—The mesozoic history of the extra-peninsular tracts is even more meagre than is that of the peninsular area. Of triassic rocks no trace is known in Sind, none of the formations of that province being of older date than cretaceous; but it is highly probable that triassic strata may exist near Kelát in Baluchistan, as *Ceratites* and *Orthoceratites* have been obtained there. Ceratite beds, probably of Bunter or lower triassic date, are found in the western part of the Salt Range of the Punjab, and in some of the ranges west of the Indus near Isakhel (Esakhel), but have not been clearly shewn to occur elsewhere; although representative beds may possibly be found in the Himalayas. The overlying beds in the Salt Range are poorly fossiliferous. In Hazára, the upper triassic or rhætic beds with *Megalodon* and *Dicerocardium* alone contain distinctive fossils, the underlying strata being destitute of organic remains; whilst the next beds in ascending order, though probably of rhætic age, contain no characteristic forms. In Northern Kashmir, and throughout the mountain region to the south-east as far as Spiti, and probably farther, resting upon the carboniferous rocks, there is a well-developed series of triassic

beds, commencing at the base, where best known and exposed, in Spiti, with a band of limestone, abounding in *Halobia lommeli*, and resting upon carboniferous beds with *Spirifer keilhavii* and *Productus semireticulatus*. Above the *Halobia* band are beds of concretionary limestone with numerous fossils, many of them similar to those of the upper trias (Hallstädt and St. Cassian) in the Alps. These Himalayan rocks are the Liláng series of Stoliczka, and in places exceed 2,000 feet in thickness. They were classed by Stoliczka himself as upper triassic, or Keuper; but other writers are inclined to consider them more probably of middle triassic age. The next formation in ascending order, the Pára limestone, some hundreds of feet thick, contains *Dicerocardium himalayense* and *Megalodon triqueter*, the latter characteristic of the Dachstein limestone in the Austrian Alps; and above the Pára limestone is the Tagling limestone, 2,000 feet thick, and containing in its lower beds fossils characteristic of the Kossen beds, the characteristic rhætic formation or *Avicula contorta* zone of the Alps, and in its uppermost strata several forms typical of the Alpine liassic beds of Hierlatz.

To the eastward, marine triassic rocks have only been detected in Burma, where *Halobia lommeli* has been found. This, however, is a species of almost world-wide distribution, and consequently of but small value as evidence of any exact horizon. It is impossible to found on this isolated occurrence any conclusions as to the triassic seas of the Burmese area being connected or unconnected with those of the North-West Himalayas.

The triassic and rhætic beds of Western Tibet and the North-West Himalayas are found represented as far north as the Mustágh Range; and the upper triassic beds are widely developed to the northward of the Kuenlun, in the mountains to the north and west of Eastern Turkestan.

A remarkable peculiarity in the triassic fauna of the North-West Himalayas, or rather of Western Tibet (for the area of Spiti, Zánskár, &c., is trans-Himalayan, and inhabited by Tibetans), is the similarity of the fauna throughout the whole series to that of the corresponding beds in the Alps. It is true that the sub-divisions of the strata do not always precisely correspond; but the community of specific forms is such as to render it highly probable that the seas of the two areas must have been united throughout the period. But, at the same time, some land connexion between India and Europe is indicated by the appearance of Karharbári plants in the European lower triassic, and of Panchet species in the rhætic. It is difficult to say whether the trias of the Salt Range was deposited in a different sea from that of Hazára, Káshmir, and Spiti; but the fossiliferous Salt Range beds appear to be older, and the absence of any lower triassic strata between the *Halobia* limestone and the

carboniferous Kuling series, together with the non-appearance of the characteristic upper triassic and rhætic fossils in the Salt Range, although some of them are found in Hazára, and perhaps farther to the westward, may indicate a distinction between the marine areas.

Except in the upper beds of the Tagling limestone, no representatives of the true liassic fauna are known to occur in the neighbourhood of India. The extra-peninsular jurassic formations, although more extensively developed than the triassic, are only known with certainty to exist in the Western Himalayan and Tibetan area and in the Punjab. Jurassic *Cephalopoda*, as well as triassic and cretaceous forms, are said to have been brought from Kelát. The jurassic rocks of the Salt Range have already been noticed in connexion with the closely allied and better developed series in Cutch; and it was shewn how the oolitic formations of the two areas were connected by outcrops in the deserts of Western Rájputána, and were doubtless deposited in parts of the same sea. The upper jurassic rocks of Hazára are more closely connected with those of Spiti.

Above the rhætic and liassic Tagling limestone in Spiti, some slaty beds, with fragments of *Belemnites*, a *Posidonomya*, and other ill-marked fossil forms, occur, and then black, friable shales, with calcareous concretions. These, the Spiti shales of Stoliczka's classification, are generally 200 to 300, rarely 500, feet in thickness, and abound in fossils, especially *Ammonites*. The fauna was classed as middle jurassic (lower to middle oolitic) by Stoliczka; but his views have since been questioned, and it now appears more probable that most of the fossils are upper jurassic (Kimmeridge and Portland); though it yet remains to be seen whether distinct zones can be traced. If they can, some may be older. Above the Spiti shales, the Gieumal sandstone, 200 to 600 feet thick, is found, and consists chiefly of a pale-coloured grit, poor in fossils. The few mollusca that occur are mostly ill-preserved and uncharacteristic bivalves.

To the eastward the jurassic rocks are traced for some distance, being found in Ngári-Khorsum, and probably much farther in Tibet; and it is said that *Ammonites* of the same species as those of Spiti are brought from the neighbourhood of Lhassa. North of the Indus, however, and in Northern Kashmir, jurassic beds do not occur. In the Northern Punjab, representatives of both the Spiti shales and the Gieumal sandstone, possessing the same mineral characters as in Spiti, reappear in Hazára, and are traced to the westward, where, however, they lose their distinctive mineral characters.

Although the fauna of the Spiti shales is believed to indicate the same upper jurassic age as that of the Katrol and Umia beds of Cutch, there is but little resemblance in the fauna. Only five species of Hima-

layan jurassic *Cephalopoda* are recognised by Dr. Waagen as identical with those of the Cutch beds; and even of these, one is a species found only in a lower sub-division in Cutch. Whilst numerous Central and Western European forms are found in the Cutch beds, only one such species is known from the Spiti shales, several, at first referred to European species, having since been considered distinct. On the other hand, there is some similarity of facies between the Spiti shales fauna and that of the Russian oolite. The Spiti jurassics occupy an elliptical tract, extending to the west-north-west as far as Zánskár; but doubtless owing its present restricted area in great part to denudation, as outliers occur to the eastward.

The characteristic *Trigoniæ* of the Umia beds of Cutch are found in beds representative of the Gieumal sandstone in Southern Hazára. It may be remembered that these same *Trigoniæ* are also found in the uppermost jurassic beds on the east coast of the Indian Peninsula, where the few marine fossils occurring in the jurassic Upper Gondwána beds at a lower horizon appear different from those of Cutch. This wide dispersal of a similar fauna at the close of the jurassic period may indicate depression of land and a free communication between the seas, in which the marine beds of the east and west peninsular coasts, the Punjab and Spiti, were deposited. It is possible that about this time the direct land communication with Africa was broken up into islands; though, as has already been shewn, the connexion was probably re-established in cretaceous times.

The cretaceous rocks of the extra-peninsular regions to the east and south-east, in Assam and Burma, have already been noticed: those to the west and north-west are too few and scattered to furnish much information. Doubtless, the greater portion of the cretaceous marine deposits are concealed beneath tertiary formations. Neocomian beds have been found in the western continuation of the Salt Range, beyond the Indus; upper neocomian or Aptian, as already noticed, in Cutch; gault in Hazára, and some beds of uncertain age near Kohát. Upper cretaceous beds, in the form of hippuritic limestone, occupy an enormous area in Persia, and were very possibly originally continuous with similar rocks in Southern Europe. It is not known how far this formation extends in the direction of India. Cretaceous rocks are well developed around Kelát and in some other parts of Baluchistan, and in all probability occupy a large area just west of the British frontier; but no details have been ascertained as to the sub-divisions represented. Away to the northward in Spiti, and again still farther north beyond Chángchenmo, on the frontier of Khoten, beds containing hippurites have been detected,

those in Spiti being the Chikkim beds of Stoliczka; and in Lower Sind at one locality a hippurite has been found in a limestone, the lowest bed exposed; but the Himalayan beds are merely fragmentary outliers, left on the top of hills, and the Sind exposure is a small inlier, seen in one spot only. Above the limestone in the last-named locality are the coarse sandstones, in which, as already mentioned, a flow of Deccan trap is intercalated; and to the sandstones succeed some soft olive-coloured shales and sandstones containing *Cardita beaumonti* and other fossils, and capped by the highest trap-flow. These sandstones and olive shales are of a very high cretaceous horizon, and are doubtless littoral beds. Similar strata are found in the Salt Range of the Punjab; but in a section examined to the west of the Sind frontier both the olive beds and the trap were wanting. It is very probable that the eastern shore of the upper cretaceous sea passed from Sind to the Salt Range and then northward; but the data are very imperfect. Far away to the north-east in Tibet, and to the west of Lhassa, a species of *Glauconia* (or *Omphalia*) has been found, which may indicate the existence of upper cretaceous beds, probably littoral or estuarine.

Tertiary rocks.—The eocene rocks afford a far better conception of the physical geology of North-Western India. By far the most important, and, so far as is known, the most complete, series of tertiary formations yet examined is found in Sind, where above the upper flow of Deccan trap, sandstones, above 2,000 feet thick, probably of freshwater origin, are found, passing up into the marine Ranikot beds, with a lower eocene fauna. To these succeed the nummulitic limestone or Khirthar group, 500 to 3,000 feet thick; a distinctly marine formation in general, but passing locally into a mass of sandstones and shales having a littoral aspect. The uppermost bands of limestone contain a different fauna; the *Foraminifera* especially being distinct from those of the Khirthar group, and including but two species of *Nummulites*, one, *N. garansensis*, found only in upper eocene and lower miocene beds in Europe, and a second, *N. sublævigata*, peculiar to India. With these upper limestones, sandstones and shales are intercalated; the marine beds soon die out, and a great thickness of sandstones without marine fossils, and probably of freshwater origin, succeeds. The whole of these beds, from the limestones with *Nummulites garansensis* upwards, including 4,000 to 6,000 feet of strata, are classed as the Nari group, and believed to represent the upper eocene and lower miocene of Europe. The Gáj group, 1,000 to 1,500 feet thick, comes next, chiefly composed of marine beds, with an upper miocene fauna; the uppermost layers, however, containing estuarine shells, and passing into freshwater, probably fluviatile, clays

and sandstones, with mammalian bones. These last beds form the lower Manchhars, and are believed to represent the Lower Siwaliks, or Náhans, of the Sub-Himalayan area. The whole Manchhar group comprises in places 10,000 feet of beds, chiefly sandstones and clays, capped by coarse conglomerates, and is considered equivalent to the uppermost miocene and pliocene of Europe. With the exception of occasional estuarine beds near the base, the Manchhar group appears entirely of freshwater origin.

The miocene Gáj beds are not traced north of Sind; in the Punjab the only marine tertiary formations known are of eocene age.

The eocene beds in the Salt Range of the Punjab appear closely to resemble those of Sind, except that the Nari group has not been detected in the former locality: in both cases sandstones and alum clays with lignite underlie the nummulitic limestone. The lówest eocene marine beds in the Salt Range, however, are beneath the lignite and alum group; whereas in Sind the Ranikot marine beds overlie a precisely similar formation; and consequently some cocene fossiliferous bands of the former locality may be older than any Sind tertiary beds—a distinction apparently confirmed by the fauna. Above the nummulitic group in the Salt Range there is a break in the sequence, neither Nari nor Gáj beds being known; and it is even doubtful whether the lowest members of the Manchhar or Siwalik group are represented. To the westward, in Kohát, the limestone is thinner, and marls, clays, and sandstones are intercalated; the underlying lignite and alum clay group appears to be wanting, or replaced by red clays, resting upon gypsum and a bed of rock-salt, 300 to 700 feet thick, and probably even thicker in places. Above the nummulitic limestones are upper tertiary sandstones and clays of freshwater origin, as in the Salt Range. In the Eastern Punjab, along the base of the Himalayas, the tertiary rocks consist of two series, unconformable to each other in the Simla area, but undistinguishable by any break farther to the north-west: the lower or Sirmúr beds, comprising three groups, known in ascending order as Subáthu, Dagshai, and Kasauli; and the upper or Siwalik series, composed of lower Siwalik or Náhan beds, middle and upper Siwaliks. Marine beds are confined to the lowest or Subáthu group, which corresponds to the Khirthar group of Sind. Lastly, in the extreme north of the Punjab, the nummulitic limestone of Hazára, Chita Pahár, the Afridi hills, &c., is interstratified with shales, and much contorted and hardened. It is separated from the newer tertiary beds by a line of fault or disturbance. Some bands containing nummulites are found at the base of the overlying rocks, and are evidently of eocene, though perhaps of upper eocene, age; but the whole series above them, consisting of the Murree beds and the Punjab representatives of the

Siwaliks, although attaining an enormous thickness, and occupying a very large extent of country, is destitute of marine bands, and even of well-marked sub-divisions.

The massive nummulitic limestone is probably an open-sea deposit; but, despite its thickness, it varies so much in composition, and passes so often into sandy and shaly beds, as to indicate in many places the vicinity of land. It is well developed throughout the greater portion of Sind, and is found represented in the middle of the Indus valley, near Sukkur (Sakhar) and Rohri, and to the eastward, between Rohri and Jesalmir (Jeysulmere). It extends throughout a great portion of the Sulemán range, and appears, as just shewn, in the Salt Range of the Punjab, and again in the Northern Punjab. To the westward, it is known to stretch through Baluchistan and Persia to the Caucasus and Asia Minor, and thence into Southern Europe. Eastward from the Salt Range, although marine nummulitic beds are found over a considerable area, the interstratification of sandstones and shales, often with terrestrial plants in places, shews the deposits to have been more or less littoral. With the data already given, an attempt may now be made at tracing the Indian coasts of the nummulitic sea.

So far as the eocene beds of Southern Baluchistan are known, they consist of sandstones and shales, and indicate the neighbourhood of land at the period of deposition. This is the case north of Gwádar, and again near Karáchi. The nummulitic limestone thins out greatly, and becomes intercalated with shales and sandstones, in Southern Sind, in Cutch, and in Guzerat. This occurrence of littoral beds along the present coast line may shew that land existed either to the southward, in the area now occupied by the Arabian Sea, or to the north-west. The absence of any eocene marine beds on the coast of the Indian Peninsula, from north of Bombay to the mouth of the Ganges, renders it probable that a considerable expanse of land existed at this epoch; and the land area may very possibly have extended towards Africa, as in cretaceous times, and probably in the miocene period. From the neighbourhood of Surat the nummulitic shore probably extended to the east of Kattywar and Cutch, then possibly, and at a later period certainly, islands, and thence ran through the western portion of the great desert to the Punjab. The sea extended to the north-east as far as Gahrwál, where the most eastern patch of Subáthu beds occurs; but there is no evidence of marine conditions in the Ganges valley between Kumaun and the Gáro hills, south of Assam. The Subáthu nummulitic beds are clearly littoral deposits, and by their aid we may trace the shore line along the south of the Himalayas to the Pir Panjál. The nummulitic limestones of Hazára and

the hills of the Northern Punjab near Attock and Peshâwar are all interstratified with shales; but the formation is of great thickness, and may have been formed in the open sea. That the sea extended northward, is shewn by the existence of nummulitic beds, much altered, in the Upper Indus valley; but they appear to be restricted to the neighbourhood of the river, and it is probable that they were deposited in an arm of the sea, while the surrounding area of Western Tibet was dry land.

It is impossible to say how far eocene rocks can be traced to the north of the Himalayas, in Tibet and Central Asia: some supposed nummulitic beds north of Sikkim have not been sufficiently identified for certainty. Marine eocene beds are found to the south of the Himalayan axis in the Assam range, and thence to the southward, throughout a considerable area, in Burma, west of the Irawadi. Many of the rocks are somewhat altered, and fossils, although found in many places, are often wanting throughout large areas. The marine nummulitic formation has not been observed in Tenasserim; but it is probably continued in the Andamans and Nicobars, and it reappears in Sumatra, Java, and other islands of the Malay Archipelago. Throughout this eastern region freshwater beds with coal are of common occurrence in the eocene rocks; and even in the marine beds coarse sandy deposits frequently indicate deposition near a shore. It is highly probable that the metamorphic area of Eastern Burma was land in the tertiary period, and that the older tertiary deposits of Assam, Burma, and the Malay islands were formed in a deep gulf, or around and amongst an archipelago, like that now existing farther to the south-east. It will hereafter be shewn that some peculiarities of the recent fauna indicate a connexion between the Malay islands, Southern India, and Africa in early tertiary times; and a land area may have extended to the south of India at this period.

Distribution of eocene land.—It will thus be seen that the Peninsula of India in eocene times was part of a tract of land, perhaps of a great continent united to Africa; that there was a sea to the eastward, extending far to the north-east, in the region now occupied by the Assam hills, and another sea to the north-west, covering great part, if not the whole, of Persia, Baluchistan, the Indus plain, and a portion of the Upper Ganges plain. An arm of this sea extended from the north-west up the Upper Indus valley in Ladák. The Himalayas, and perhaps Tibet, wholly or in part, were raised above the sea; but formed in all probability land of moderate elevation. Whether the Himalayan land was united to the Peninsula is, of course, uncertain—but very probably it was; for there is no evidence of marine conditions having existed in the Ganges plain to the east of the Dehra Dún; and if the ferruginous bands of the

Subáthu group be laterite, as they appear to be, the trappean detritus composing them must have been derived, in all probability, from the peninsular area; and the latter must consequently have extended northward, to the base of the Himalayas, in the neighbourhood of Umballa.

It is probable that in the later eocene period of the Nari and Dagshai beds, the sea still flowed as far north as the Punjab; for some Nari *Foraminifera* has been found in that direction: but it is evident that the marine area was diminishing; for the mass of the Nari beds, even in Sind, appear to be of freshwater origin. In miocene times, although marine conditions prevailed throughout Western Sind, the area of the sea was very much smaller than in the eocene period; for all the marine beds of the Punjab and Sub-Himalayas are destitute of marine fossils, and are probably fluviatile deposits.

Later tertiary beds.—East of the Indian Peninsula the area of middle tertiary rocks can be but ill defined for want of information. Marine beds of this age are found in Pegu occupying an extensive area; and if, as appears probable, some marine deposits in the Gáro hills, resting unconformably on the nummulitic limestone, are of miocene age, the difference in extent between the lower and middle tertiary seas in the Bay of Bengal area was probably less than to the westward. All pliocene beds in Assam and Burma appear to be of freshwater origin, with the possible exception of some in the Gáro hills; indeed, after miocene times, the land areas of South-Eastern Asia must have assumed to a great extent their present contour. It has already been pointed out that, for the first time in geological history, the delimitation of the Malabar coast line is indicated in the miocene period.

Some marine beds of late tertiary age, largely developed along the coast of Baluchistan, and hence called the Makrán group, are very probably marine equivalents of the Manchhars and Siwaliks. This would be in favour of the Baluchistan coast line having also assumed its present approximate outline in later tertiary times. The indications of a connexion of land between India and Africa in the tertiary period, as illustrated by the recent fauna, will be discussed in the sequel.

Siwalik fauna.—The mammalian fauna of the later tertiary deposits has received more attention than the fossils of most Indian formations. A most important and interesting assemblage of mammalian remains has been preserved in the middle and upper Siwaliks, the two highest groups of the Sub-Himalayan series. In these beds 84 species of mammals have hitherto been detected, belonging to 45 genera, the whole assemblage having more resemblance to the miocene of Europe than to any later European fauna, but containing a larger proportion of recent genera, and

especially of ruminants, than is found in the miocene elsewhere. Of the associated reptiles, several are recent species; and all the freshwater and land shells found appear to be identical with living forms.

The Náhan beds, forming the lowest group of the Siwalik series, have hitherto proved unfossiliferous; but in the Lower Manchhar beds of Sind, teeth and other remains of a considerable number of species have been found, chiefly of *Ungulata*, comprising, together with several Siwalik species, some genera not known in the Siwalik fauna, and having an older facies. The number of recent genera and of ruminants, in the Manchhar fauna, is very small, whilst several typically miocene genera occur, unknown in the beds of the Siwalik hills. There appears good reason to believe that the Siwaliks and the Manchhars are approximately equivalent, and that the Lower Manchhars probably correspond to the Náhan group. As, however, the Manchhars rest upon the Gáj beds, which are probably upper miocene, it is evident that the Siwalik fauna cannot be older than pliocene. The Siwalik mammalia resemble those of Pikermi in Attica more than any other known fossil fauna; and the Pikermi beds, although they contain a large number of miocene species, and are frequently classed by various writers as miocene, are shewn to be really of pliocene age by containing, at their base, pliocene marine fossils.

Remains of mammalia of Siwalik species have also been found at Perim Island in the Gulf of Cambay, off the coast of Guzerat, and in the later tertiary beds of Burma, which, like the Manchhar beds, overlie miocene marine strata. In both cases the fauna, so far as known, is comparatively poor; but in each instance there is about the same proportion of Siwalik species. There is nothing to indicate that the fauna of the Irawadi beds is older than that of the Siwaliks; and the Perim Island mammalia, although comprising *Dinotherium*, and wanting some of the recent genera found in the Siwalik beds, appear to be of nearly the same age as the latter. It must be inferred, therefore, that in pliocene times there was land communication between the Sub-Himalayan area, Guzerat, and the Irawadi valley.

The valley gravels of the Indian Peninsula, and especially some fossiliferous beds in the Narbada valley, contain a few Siwalik mammalia, associated with species more nearly allied to those now living. Remains of human implements have also been detected in these gravels, which are probably of post-tertiary or pleistocene age.

The marked resemblance between the Siwalik fauna and that of the European miocene may be due to a migration to the southward of the fauna inhabiting Northern Asia and Europe towards the close of the miocene period, when, as is known from other data, the temperature of the northern hemisphere was becoming colder. There is a marked affinity

between the Siwalik fauna and that now found in the Indian Peninsula, an affinity much greater than there is between the Siwalik and Malay fauna; and several genera of Siwalik mammals no longer living in India are found still existing in South Africa. This may be due to the admixture of the fauna inhabiting India in pre-Siwalik times with the Siwalik immigrants; for, as will be shewn, there is a probability that the Ethiopian elements of the Indian and Malay faunas are descendants of earlier immigrants than the pliocene Siwalik types; or (and this is perhaps the more probable view) the existing mammals both in India and in Africa are descended in part from the miocene inhabitants of Europe and Northern Asia, driven southward at the commencement of the cold cycle, which culminated in the glacial epoch, and some genera which have died out in India have survived in Africa. The occurrence of so many species of the Central European miocene beds in the pliocene rocks of Greece is very possibly due to the same migration to the southward.

Origin of Himalayas.—During the interval that has elapsed since eocene times, whilst no important movements, except small and partial changes of elevation, can be traced in the Peninsula, the whole of the gigantic forces, to which the contortion and folding of the Himalayas and the other extra-peninsular mountains are due, must have been exercised. The Sub-Himalayan eocene beds were deposited upon uncontorted palæozoic rocks; and although the Himalayan area was probably in great part land at a much earlier period, there is no reason for believing that this land was of unusual elevation, whilst the direction of the Himalayan ranges is clearly due to post-eocene disturbance. It will be shewn, in the chapters relating to the Sub-Himalayan rocks, that the movement has been distributed over the tertiary and post-tertiary period; and a great portion is of post-pliocene date. Indeed, the fact that earthquakes are now of common occurrence in the Himalayas, the Assam hills, Burma, Cutch, and Sind, and that many of the shocks are severe and some violent, whilst the peninsular area is but rarely affected by earthquakes, may indicate that the forces, to which the elevation and contortion of the Himalayas are due, are still in action; and that the highest mountains in this world owe their height to the fact that the process of elevation is still in progress, to a sufficient extent to counterbalance the effects of denudation.

If, as appears probable, the intercalation of a laterite bed in the Subáthu eocenes shews that the latter strata were of contemporaneous origin with the high-level laterite of the Deccan, which is always posterior in date to the Deccan traps, it is evident that the main Himalayan disturbance is of later date than the Deccan trap period; although the pre-tertiary Himalayan elevation, unaccompanied by folding, may be

older than the traps, or of the same age. In several localities along the base of the Himalayas, basaltic traps are intrusive in the old palæozoic rocks of the mountains. These traps are, however, suspected to be of later tertiary age, and newer than the Deccan traps; for they are said in one locality to penetrate the Sub-Himalayan beds, and in another locality, where Sirmúr beds are entirely composed of detritus from the neighbouring palæozoic strata, no fragments of the trap, now so extensively intruded into those strata, are found. These Himalayan intrusive rocks may be of the same date as the contortion and folding of the beds.

In Sind and the Sulemán ranges, there is much probability that some movement took place during miocene and pliocene times. Some slight unconformity between beds, elsewhere conformable, and the absence of different groups in parts of the country, may thus be explained; but the principal disturbance is clearly of post-pliocene date. To the eastward, in Burma, however, the pliocene formations of the Irawadi valley are but little disturbed, and the miocene beds, although contorted, are unaltered; whilst many of the eocene and cretaceous rocks are greatly changed, besides having undergone excessive disturbance and folding. These facts may, perhaps, indicate that the disturbing forces were more severe to the eastward in middle tertiary times, and that the main action to the westward was of later date: a view partly supported by the fact that there is evidence of elevation having taken place in the Himalayas near the Ganges and Sutlej, at an earlier period than farther to the westward. In the Simla area, there is marked unconformity, due evidently to upheaval and denudation combined, between the Sirmúr and Siwalik series, and between the lower, or Náhan, group of the Siwalik series itself and the next overlying sub-division; whereas farther west, in the Northern Punjab, all the groups follow each other in apparently conformable sequence. The evidence, however, is not sufficient to prove that the contortion to the eastward is older than to the westward; and the absence of any important break in Burma is opposed to the suggestion of great movements having taken place in that country in early or middle tertiary times.

It is evident that the forces, to which the principal ranges in the extra-peninsular area owe their direction, have not only been exerted throughout a considerable portion of the tertiary period, but that these forces have acted contemporaneously, at all events in the post-pliocene period. Yet the directions of the ranges vary in the most remarkable manner, as has already been pointed out on a previous page, and shewn on the sketch map in the commencement of the present Introduction. It would be difficult to conceive clearer evidence: taking only the north-

western area, amongst the mountain ridges that encircle the Indus plain, and comprise pliocene beds, are found ranges running north and south, as the Khirthar and Sulemán; east and west, as the Mari and Bhugti and the Afridi hills; north-west and south-east, as the Pir Panjál; north-east and south-west, as the Eastern Salt Range and Kharian hills; and many intermediate directions may also be traced, independently of curved ridges. Similar differences of direction are to be found to the eastward of India. It is manifest, in the face of so much variation in strike amongst ridges of contemporaneous origin, that arguments in favour of the connexion between distant but parallel ranges should be received very cautiously; and the establishment of cotemporaneous "systems" must depend upon more valid data than the direction of mountain chains.

What the forces can have been that produced the great disturbance and folding of the rocks manifested in the various mountain chains is so difficult a subject, that nothing would be gained by discussing at length the various guesses—for they are little more—hitherto put forward. The only point on which most modern geologists appear to be agreed is, that lateral pressure has been exercised; and by many writers the lateral pressure is attributed to shrinking of the earth's crust, through the cooling of the interior. It is evident, if this be admitted, that the pressure has come, in the case of the extra-peninsular ranges of India, simultaneously from various directions. Even the side from which the force has been exerted in each case is very far from easily determined, owing to the circumstance that the contortion of rocks is due to two opposite and equal pressures—a moving force and a resisting mass—and it is not always easy to distinguish the effect of the one from that of the other. It has been argued by Suess,[1] mainly from the resemblance between the phenomena exhibited by the Sub-Himalayan series, and especially by the Siwaliks, to the south of the Himalayas, and the features shewn by the *mollasse* to the north of the Alps, that the lateral movement, to which the contortion of the Himalayas is due, came from the north, in the same manner as the thrust in the Alps was from the south. This view of Suess, it may be stated, is in accordance with the observations of the Indian Survey, and founded upon them; and if, as appears most probable, lateral movement be accepted as the cause of mountain-formation, the southward thrust of the Himalayan mass may be a correct explanation of the phenomena. The Northern Punjab, west of the Jhelum, as Suess points

[1] Entstehung der Alpen, pp. 126—144. In this valuable work a good summary of the views of previous writers will be found, and abundant references to the literature of the subject. Some remarks bearing on the same matter will be found in Prof. Martin Duncan's Presidential Address to the Geological Society of London in 1877: Proc. Geol. Soc., 1876-77, pp. 67—69, &c.

out, has evidently been affected by a force moving from a different central area, and not by that to which the strike of the Pir Panjál and the Himalayas generally is due. One indication of this difference, and an indication which may shew that the commencement of movement was not contemporaneous in the two areas, is that, east of the Jhelum, in the Pir Panjál, there is a great break at the base of the eocene; whereas west of the Jhelum a similar break, there attributed to a great fault, intervenes between lower and upper eocene beds.

But the curves of the Salt Range, and especially the deep re-entering angle at the Indus, are so much sharper than those of the ranges to the northward, that, despite the smaller degree of disturbance in the Salt Range, there must have been in this area a thrust, or series of thrusts, from the south. This latter force may, of course, have taken the form of resistance to the northern movement; but it exemplifies the difficulty, already referred to, as to the direction of the thrust. Again assuming, as in the absence of all indication of disturbance in tertiary times in the peninsular area we must assume, that this central area remained fixed, and the crust disturbances came from without, we must suppose a lateral movement from the westward on the Western Sind frontier, from the northward in the Mari and Bhugti hills, north of Jacobabad, from the west or west by north again in the Sulemán, from the north in the Safed Koh and Afridi hills, from the north-west in the Hindu Kush and most of the Afghanistan ranges, from the north along the upper Punjab, between Peshâwar and Abottabad, and from the north-east in the Pir Panjál; from the northward throughout the greater portion of the Himalayas, from north-west (or south-east?) again in the extreme Eastern Himalayas, and from the south-east in the parallel Nága hills; whilst in Burma, as a rule, the thrust has come from the eastward. To the west of India, beyond the Sind frontier, for about 300 miles, the ranges strike east and west, shewing a thrust from north or south; thence throughout the greater part of Persia the direction of the mountain chains is north-west and south-east. The ranges of Baluchistan and Persia,[1] it should be added, are largely composed of tertiary rocks, and may probably be of contemporaneous origin with the Himalayas. Taking the Persian area and that of the Himalaya and Tibet, it will be seen that the mountain ranges fall roughly into two great curves convex to the southward; but the deeper western curve has produced the smaller mountain ranges. That a gigantic lateral movement has taken place in the apex of this western curve is, however, shewn by the fact that for nearly 150 miles between Gwádar and Jálk in

[1] Eastern Persia, I, pp. 1—17, and maps.

Baluchistan the track traverses beds, all apparently of tertiary age, at right angles to their strike, and that all these beds are vertical, or nearly so. The contraction in breadth, or, in other words, the lateral movement, must have been great to have converted horizontal formations into a series of undulations, with dips so high as those seen in the Baluchistan ranges.

Origin of Indo-Gangetic plain.—It would be unprofitable to enter into further discussion on this difficult question: the hypotheses of mountain formation require much to be added before they can be incorporated in the body of geological science, and considered as data on which to found inferences as to the history of the world. But before quitting the subject of the extra-peninsular hill ranges, a few words as to the origin of the remarkable Indo-Gangetic plain, from the outer margin of which they rise, may not be out of place. The popular conception of this plain, an idea repeated in numerous geological and zoological treatises, is that the area is an ancient sea, filled up by deposits brought in by rivers. This view is natural enough: the vastness of the plain, across which, even at its narrowest part, the highest mountains of the world are barely visible, must strike even the most ordinary spectator with its resemblance to a sea-bed. The great contrast between the Himalayan and peninsular formations, and the much greater prevalence of marine beds on the small accessible area of the northern region, also lend weight to the idea of a sea having separated the two.

It should, perhaps, be admitted at once, that, as in the majority of geological speculations, the evidence is imperfect, and the greater portion is negative. There is absolutely no proof of any sort or kind, that the whole Indo-Gangetic plain has at any time been a marine area; but there is equally no proof that it has not. It has been shewn that, in eocene times, the sea occupied the Indus valley as far as the foot of the Himalayas, and extended along what is now the base of the mountains, as far east as Kumaun; and also that marine conditions prevailed to the north-west throughout a great part of the tract now occupied by the Assam range; but it was also pointed out that, in the area between Kumaun and the Gáro hills, no trace of marine formations had been found. Yet it is difficult to understand, if the Gangetic plain was a sea-basin, why no marine beds occur. It is true that the northern border of the plain, throughout the most important part of the intervening space in Nepál, is unfortunately inaccessible to Europeans; but still, if the Gangetic plain in any way corresponds to an eocene sea, as the Indus plain doubtless does, why are no traces of marine beds found to the south of the valley, on the margin of the peninsular area, as they are in the desert to the east of the Indus? In the Brahmaputra plain, also, no

marine deposits of tertiary age are found; in the plain itself only fluviatile deposits have been detected, and the marine eocene and miocene beds are confined to the southern slopes of the range, forming the southern watershed of the valley.

It was shewn that the jurassic traps of the Rájmahál hills, west of the Ganges delta, were very possibly once continuous with those of Sylhet, east of the deltaic area; that the coast line, in cretaceous times, ran from the present eastern coast line of the Peninsula to the Assam Range; and that there is no indication of any cretaceous bay running up the Ganges valley; but, on the contrary, the absence of any marine deposits between Rájámahendri and the Gáro hills rather indicates that the old coast line ran across what is now the Bay of Bengal. It is far from improbable that the nummulitic coast line approximately coincided with that of cretaceous times, as the cretaceous shore nearly followed the old line traced in the upper jurassic period. Miocene marine deposits are to the eastward similarly restricted to eocene, and more so in Western India. As already noticed, it appears certain that those tracts in the Punjab, which had been marine in eocene days, were land in the miocene epoch and in later tertiary times: the immense thickness of upper tertiary beds of freshwater origin, now upraised along the western and northern border of the Indo-Gangetic plain, from the mouths of the Indus to the eastern end of the Assam valley, negative the idea of marine conditions. The occurrence of the same mammals in the pliocene beds of the Sub-Himalayas and of Perim Island has already been noticed as evidence of land communication between the two areas. Amongst still later beds, the post-tertiary formations of the North-West Provinces are clearly river deposits; and in Calcutta itself, within the tidal creeks of the delta, a boring to a depth of 480 feet, 460 being beneath the present sea-level, traversed beds in which the only fossils observed were terrestrial or fluviatile. These beds, moreover, comprised gravel too coarse to have been deposited in an open sea; whilst at 385 feet from the surface a peat bed was found, clearly of terrestrial origin. All tends to shew the gradual depression of an area composed of fluviatile formations throughout all the later tertiary periods. The sea may, at times, have extended some distance from the present coast; for it is improbable that sinking and the deposition of sediment can have gone on so evenly, and that land only just above high water has always been kept at the same relative level, despite ages of depression; but there is nothing in the data known to indicate marine deposits.

In the neighbourhood of the Indus delta the sea probably extended some distance inland at a late period; and both Cutch and Kattywar may

have been islands at a very recent geological epoch. It is clear, however, that the two species of Siwalik elephants, and the buffalo found in the Narbada gravels, could not have traversed the Indo-Gangetic plain, had it been occupied by the sea in pliocene or post-pliocene times. It will be seen that the number and variety of data opposed to the idea of a sea having intervened in the place of the Indo-Gangetic plain between the Peninsula of India and the remainder of Asia during or since the tertiary epoch are considerable, and all the facts are adverse. It must also be manifest that there is no evidence that any such depression as the Indo-Gangetic plain existed in pre-tertiary days; for if it had, we should probably find marine jurassic or cretaceous rocks along the foot of the Himalayas, if not on the margin of the peninsular rock area also.

Thus we are brought in face of a very important conclusion; and it becomes highly probable that the Indo-Gangetic depression is of contemporaneous origin with the disturbance and contortion of the Himalayas and the other extra-peninsular ranges, and that the physical features of the two areas are closely connected. The coincidence in general outline, the parallelism in fact between the great area of depression and the ranges north, east, and west of it, tends to confirm this view. The plain of the Ganges and Brahmaputra continues along the foot of the Himalayas throughout; the Indus plain turning southward where the ranges in the Western Punjab and Sind run north and south, and the estuaries of the Ganges and Brahmaputra being similarly deflected in front of the north and south hills of Tipperah and Chittagong. It is not unreasonable to believe that the crust movements, to which the elevation of the Himalayas, and of the Punjab, Sind, and Burmese ranges are due, have also produced the depression of the Indo-Gangetic plain, and that the two movements have gone on *pari passu*. That the depression of the deltaic area of the Ganges is still in progress, is shewn by a series of facts, of which the evidence afforded by the Calcutta bore-hole is one; and it has already been suggested that the disturbing forces affecting the Himalayas are still in action.

Now, there is a theory, originally attributed to Prévost, but largely adopted and modified by later geological writers, that the elevation of mountains is due to the depression of a neighbouring area. It is clear that if an arc of a circle tends to become flatter, and to approximate to a straight line, the horizontal extent must be increased, because every arc of a circle is longer than its chord. If one portion of a rigid circle be slightly depressed, a neighbouring portion, being compressed into less horizontal space, and having in fact the length of its chord diminished, must bulge out. Applying this fact to the earth's surface, it is clear

that the depression of any portion would produce lateral thrust, and this might cause the bulging of a neighbouring area. Of course, there is a limit: after a certain amount of depression, the arc and chord would coincide in direction, and farther depression would cause the surface to take up less space horizontally, instead of more. The depressions have been called geosynclinals, and the elevations geanticlinals by Dana.

At first sight it would appear as if the theory, as applied to mountain formation, depended partly on the assumption of the earth's internal fluidity; but a little reflection will shew that such is not the case; greater radial contraction of one segment of a sphere, or of one portion of any great circle intersecting the sphere, would depress the surface; and if the superficial portion did not contract equally, would cause lateral pressure. It is assumed, it should perhaps be stated, when changes on the earth's surface are attributed to the shrinkage of the interior through cooling, that the crust, having already cooled, would not contract in proportion.

A very simple calculation, however, shews that the depression, even of so large an area as the Ganges plain, could not have produced the elevation of the Himalayas. The Himalayan belt, between the plains of India to the south and the line of the Indus and Brahmaputra or Sangpo to the north, has an average breadth scarcely, if at all, inferior to that of the Gangetic plain, even if the plateau of Northern Tibet be omitted from the calculation, and supposed to owe its elevation to movements in Central Asia. Assuming that both the Himalayan and Gangetic areas originally differed but little in elevation, it is clear that the Himalayan portion of the arc of a great circle has been raised to the maximum height of the peaks, or 29,000 feet, in addition to all that has been removed by denudation. If the two arcs, that across the Himalayas and that across the Gangetic plain, be approximately equal, in order to produce a lateral thrust sufficient to raise the former, the surface of the latter must be capable of sinking through about an equal distance. The amount is not exactly the same; but in arcs of so small angular dimensions the difference would be trifling. Now, the arc subtended by the Gangetic plain is about 3°, and the height of such an arc of the earth's surface above the chord, or the distance through which the surface could sink and still produce lateral pressure, is only 7,000 feet; whilst the difference in length between the arc of 3° on the earth's surface and the chord of that arc is only about 126 feet. That is to say, the depression of the Gangetic plain could only have produced a lateral movement of 126 feet, and have raised the Himalayas to an elevation of 7,000 feet, provided all the lateral movement was expended in producing elevation.

It is thus evident, independently of the circumstance that the lateral movement appears to have come from the north, that neither the elevation nor folding of the Himalayas is due to the depression of the Gangetic plain alone. The formation of the Indo-Gangetic depression and of the Himalayas and other mountain chains is probably due to the same forces, without the one being in any way the cause or effect of the other.

Distribution of recent fauna.—There is still one question to be noticed before quitting the subject of Indian geological history: this is the light thrown by the distribution of living animals in different parts of the world on former connexions between India and other regions. The geographical distribution of animals has been very fully treated by Wallace,[1] who, following Sclater and some other naturalists, divides the surface of the globe into six great regions: (1) the Palæarctic, including Europe, Africa north of the Sahara, and Asia north of the Himalaya; (2) the Ethiopian, comprising the remainder of Africa, with Southern Arabia and Madagascar; (3) the Oriental, consisting of India, Southern China, Burma, Siam, &c., the Malay Peninsula, the Philippines, Sumatra, Java, Borneo, and the other Malay islands, to "Wallace's line" between Bali and Lombok; (4) the Australian, comprising the south-eastern islands of the Malay Archipelago, Celebes, New Guinea, Flores, Timor, &c., Australia, New Zealand, and all the islands of the Pacific as far east as the Sandwich, Marquesas, and Low Archipelagoes; (5) Nearctic; and (6) Neotropical, approximately corresponding to North and South America.

The classification adopted is open to some objections: the regions named are by no means equivalent to each other, and it is a question whether several do not require further sub-division. The differences between the Indian and Australian faunas, although the two regions are only separated in places by a few miles of sea, are very much greater than the distinctions between the animals inhabiting the comparatively distant Oriental and Ethiopian regions. Several other classifications have been proposed by Murray,[2] Blyth,[3] Von Pelzeln,[4] and others; all of whom agree in classing either the whole Oriental region, or a portion of it, in the same great sub-division with Equatorial and Southern Africa, or else in distinguishing Peninsular India as a region apart. There can be no question about the existence of a marked distinction between the

[1] Geographical Distribution of Animals, 2 vols., 1876.

[2] Geographical Distribution of Mammalia, 1 vol., 1866.

[3] "Nature," 1871, March 30, p. 427; Journ. As. Soc, Bengal, 1875, pt. 2, extra number; Introduction, p. xiv.

[4] Afrika—Indien: Verh. k.-k. Zool. Bot. Gesellsch., Wien., 1875, pp. 62, &c.

fauna of the greater part of the Indian Peninsula and that of the countries east of the Bay of Bengal; but as the question is an open one, it is convenient to adopt Wallace's nomenclature and limits for the present, so far as the great regions are concerned. It must, therefore, be understood that the territories and dependencies of British India, with the exception of the Himalayas, above about 7,000 to 10,000 feet elevation, are classed as belonging to the Oriental region; the higher portions of the mountains, together with the trans-Himalayan countries, belonging to a province of the Palæarctic region. In North-Western India, however, there is so large an admixture of Palæarctic forms, that no definite line can be drawn between the two faunas; Kashmir, for instance, and the North-Western Punjab near Peshâwar, having almost an equal proportion of types belonging to the two.

It is, however, impossible to assent without modification to the sub-divisions or sub-regions of the Oriental region proposed by Wallace. They are four in number: (1) the Hindustan or Indian sub-region; (2) the Ceylonese and South Indian; (3) the Himalayan or Indo-Chinese; and (4) the Indo-Malayan. The Himalayan includes Siam, Southern China, and all Burma, except the extreme southern portion of Tenasserim: the latter, with the Malay Peninsula, belongs to the Indo-Malayan sub-region. This division between the two sub-regions, so far as British territories are concerned, is correct; and the minute details of the great Indo-Chinese sub-region are not of so much geological interest as the distribution of the fauna in the Indian Peninsula and its outskirts. From Wallace's Indian sub-region the Indus plain and the desert to the eastward must be separated and classed with the Baluchistan coast-land as a distinct sub-region, having a characteristic dry climate fauna and flora, with a large intermixture of Palæarctic forms; whilst the limits of the Ceylon and Southern Indian province require alteration. This sub-region, a very important one, with a peculiar fauna, having some marked affinities to that of the Malayan countries, comprises the whole Western or Malabar coast of the Peninsula, from north of Bombay to Cape Comorin; but not the central highlands nor the Coromandel coast, although several isolated hill-groups, such as the Shivarais, south-west of Madras, possess, on their higher elevations, a Malabar fauna and flora. This sub-region is better distinguished by the name of Malabar; it comprises the hills of Southern Ceylon, but not the plains forming the northern portion of the island.

It is of course unnecessary to enter here at any length into the peculiarities of the fauna: the points to which attention is desirable is such evidence of former connexion with regions, now separated by impassable

barriers, as is afforded by the existence of allied animals. As might be anticipated, a few Palæarctic forms are common in those parts of the Oriental region nearest to the Palæarctic boundary, and the number of such forms diminishes to the southward.

The importance of these types is derived from the fact, that they require careful distinction from Ethiopian genera; for there is a similar admixture of Palæarctic forms in the Ethiopian region. In the same manner several distinctively Malayan and Himalayan forms, of birds especially, are common in the Indian Peninsula, independently of the peculiar forms with Malay affinities in the Malabar sub-region; and it is probable that Malayan forms are, in many cases, recent immigrants.

Mammals and reptiles, owing to their more limited powers of migration, afford better indications of a former continuity of land than birds; whilst freshwater fishes and other animals inhabiting rivers and lakes suffer from the serious disadvantage that, whilst the exact method by which they, or their ova, are transported, is not clearly understood, there is no doubt that they are capable of being carried alive from one piece of water to another by some natural agency. Hence the limits to their range are imperfectly known. The past history of land invertebrates is too imperfectly ascertained for the facts of their present distribution to be equally intelligible with that of vertebrates. On the whole, although the past history of mammalian vertebrates is still very imperfectly understood, it probably affords more data by which the probable migrations and origin of living species can be traced, and inferences drawn as to the original distribution of land, than does the existing knowledge of any other class of animals.

Ethiopian affinities of Oriental mammals.—Comparing, then, the mammalian fauna of the Oriental region, as a whole, with that of the three neighbouring regions, it will be found at once, that the strongest affinities are with the most distant of the three—the Ethiopian. Out of 35 families of terrestrial *Mammalia* ascribed to the Oriental region by Wallace, four are peculiar, or nearly so, viz., *Tarsiidæ*, *Galeopithecidæ*, *Tupaiadæ*, and *Æluridæ*; one, *Tapiridæ*, is found also in the Neotropical region only, and six only (excluding stragglers in Celebes, and one or two of the other islands having an intermediate fauna) are found in the Australian region; four of these being bats, and a fifth, *Suidæ*, only extending beyond the confines of the Oriental region as far as New Guinea; so that the only terrestrial wingless mammalian family common throughout is the almost cosmopolitan *Muridæ*. The number of Oriental families found in the Palæarctic region is 21, whilst no less than 28 are common to the Oriental and Ethiopian faunas. Omitting such cosmopolitan families

as *Vespertilionidæ*, *Soricidæ*, *Muridæ*, *Felidæ*, &c., the numbers are 13 and 19. The families found in the Oriental and Palæarctic regions, but not in the African, are *Talpidæ*, almost confined in the former to temperate portions of the Himalayas and some other hill ranges, *Ursidæ* and *Cervidæ*. The families found in the Oriental and Ethiopian regions, but not in the Palæarctic, are *Simiidæ*, *Semnopithecidæ*, *Lemuridæ*, *Pteropidæ*, *Noctilionidæ*, *Manatidæ*, *Rhinocerotidæ*, *Tragulidæ*, *Elephantidæ*, and *Manididæ*. A species of *Semnopithecidæ* is found at a high elevation in Eastern Tibet, and another species ranges above most Oriental forms in the Himalayas; but in neither case can the animal be said to inhabit the Palæarctic region.

Of these families, the bats and dugongs may be neglected; the other families require a few words of notice. The *Simiidæ* are wanting in the Indian Peninsula, Ceylon, and the Himalayas. The *Semnopithecidæ* occur almost throughout the region; the *Lemuridæ* are represented by one genus confined to Southern India and Ceylon, and by a second genus in the countries east of the Bay of Bengal: none occur in the Himalayas, nor in the greater part of Peninsular India. The *Rhinocerotidæ* are unknown wild in the Indian and Malabar sub-regions; the *Tragulidæ* are represented by one genus or sub-genus in India and Ceylon, and by another in the countries east of the Bay of Bengal: this family, also, is not represented in the Himalayas. The *Elephantidæ* and *Manididæ* are more generally distributed. The *Rhinocerotidæ* and *Elephantidæ* had so extensive a distribution in the later tertiary period, that they furnish no inference of importance as to the former connexion of land areas; the ancestor of the existing Oriental species might have been derived from either the Palæarctic or Ethiopian region.

One remarkable fact may be gathered from these few details; and this is, that the peculiarly Ethiopian families are better represented to the south and east of the Oriental region than to the north-west. The orangs, the nearest allies of the African *Simiidæ*, are only found in Sumatra and Borneo; the lemurs are wanting throughout the northern portion of the region, and so is *Tragulus*. These forms, in fact, appear more or less isolated, as though they had formerly had a more extended range. The same thing occurs in Africa. The only Ethiopian representative of the *Tragulidæ* is confined to Western Africa; and so are the two genera of lemurs most nearly allied to the Oriental forms, and the African representative of the typically Oriental genus *Paradoxurus*. The *Simiidæ*, too, are confined to Western and Central Africa. Another curious instance of the isolation of types shewing affinity between the African and Malay faunas consists in the occurrence in Celebes, beyond the limit of the

true Oriental region, and associated with a mixed Oriental and Australian (Austro-Malay or Papuan) fauna, of a monkey, *Cynopithecus*, more nearly allied to the African baboons than to any of the Indian and Malay species. The same island possesses the peculiar bovine form *Anoa*, allied to a buffalo.

These cases of isolation probably indicate that the animals belong to an older fauna, now partly replaced by newer types, and that this older fauna was common to India and Africa. It is very probable that these animals are descended from the ancient tropical fauna of the early tertiary times. But, so far as it is possible to judge, the process of variation would have caused a greater distinction between forms so widely separated, and exposed to such different conditions, if the period of isolation were great; and it is difficult to suppose that the lands inhabited by the ancestors of the *Simiidæ*, *Lemuridæ*, *Tragulidæ*, and *Manididæ* of the Oriental and Ethiopian regions can have been separated prior to the early part of the miocene period.

It must be remembered that the whole evidence is far more extensive; the mammalia are merely selected as affording the best examples. It may reasonably be inferred that during part of the early tertiary period India was united to Africa, and the union may have been continuous from the cretaceous period to miocene times. The course of the old continent may perhaps be traced by the Maldive and Chagos archipelagos, and by the banks between the Mascarene islands and the Seychelles. That portions of the old land remained, broken up into islands, long after the connexion had been severed, is probable from some peculiarities amongst the birds of the Seychelles and Mascarene islands: thus the genus *Hypsipetes*, a characteristically Oriental form, is represented in Madagascar, Bourbon, Mauritius, and the Seychelles; and *Copsychus*, an equally typical Eastern genus, occurs also in Madagascar and the Seychelles. It is easily conceivable that birds should fly, or be blown, from island to island long after the distance was too great to be traversed by mammals. The circumstance that the mammalian fauna of the Oriental region shews less affinity with Madagascar than with that of the African continent, is perhaps due to Madagascar having been separated before the submergence of the land connecting Africa and India.

The southern portion of the Indian Peninsula with Ceylon may have been united to the Malay countries in tertiary times, perhaps later than with Africa. This, however, is not clear: despite some remarkable points of affinity to the Malay fauna, there are very remarkable differences; and when representative forms are found in Southern India or Ceylon and in the Malay countries, such forms are frequently, perhaps most fre-

quently, generically distinct. One of the most singular cases of generic alliance is the occurrence of a species of *Draco*, a Malay genus of lizard, in Malabar; but this is exceptional. Most of the genera of Ceylonese and Southern Indian lizards and snakes are peculiar; and one family of snakes is confined to the sub-region, and to some hill tops in Southern India. So far as the sea bottom between Ceylon and the Malay archipelago is known, there is nothing to indicate a former continuity of land in this direction; and the similarity of the fauna may perhaps have another explanation.

Ethiopian affinities of Indian mammals.—The affinities with the Ethiopian fauna hitherto mentioned are those of the Oriental region generally, and are, as already noticed, perhaps more marked in the southern part of that region than elsewhere; but, besides these, there are some very curious and prominent relations between the mammals and other animals of Africa and those inhabiting the Indian Peninsula alone, and not represented by any allied forms in the other Oriental sub-regions. As examples, the common antelope, *Antilope*, the nilgai, *Portax*, the four-horned antelope, *Tetracerus*, and the ratel, or Indian badger, *Mellivora*, may be quoted. In the case of *Mellivora*, the resemblance of the African and Indian forms is very great; but the antelopes are generically distinct. None of the animals mentioned is represented by allied species in Baluchistan or Arabia. These alliances to the African fauna may indicate that the Peninsula of India was united to Africa after the Malay countries had been severed; and if so, the evidence just quoted in favour of a later union between Southern India and Malayasia must receive some other explanation; but the Indian antelopes may very possibly be descendants of forms inhabiting the region in pliocene times; and the resemblance of these animals to Ethiopian types may be due to the immigration, as already suggested, of a closely allied fauna into both India and Africa at the close of the miocene epoch.

A third class of Ethiopian affinities in the fauna of Peninsular India is exemplified by the Indian gazelle and Jerboa rat (*Gerbillus*). In this case, however, closely allied species are found in the intervening countries and in the southern Palæarctic region; and the migration into India may have been posterior to the glacial epoch.

Affinities of land shells.—It should have been mentioned that the affinities of Oriental genera of land shells, and especially of the operculate forms (*Cyclophoridæ* and *Helicinidæ*), indicate an alliance with the Australian, rather than with the African fauna. Some genera certainly have extended to the Mascarene islands, Madagascar, and Africa; but they probably went from east to west, as the number decreases to the

westward. Land mollusca are very possibly of high antiquity; and the resemblance in this case may be due to the older mesozoic communication between India and Australia. The mode of migration of these animals is, however, imperfectly understood.

Survival of older types in the Indian area.—This is perhaps the most convenient place to call attention to the survival of forms in India to a later period than in Europe; several such instances of prolonged existence have been noticed, and they are not peculiar to any particular period of geological time. Amongst the cases hitherto recorded is the appearance of *Hyperodapedon*, a triassic reptile, in Indian beds of middle or upper jurassic age, and the occurrence of the triassic *Ceratodus*, and of some liassic genera of fish in the same beds. Then middle jurassic plants in Europe occur in upper jurassic beds in India; *Globosi* ammonites, not known above the trias in Europe, are found in middle cretaceous rocks in India; *Megalosaurus* and an amphiccelian crocodile, not found above lower cretaceous in the former area, are met with in upper cretaceous strata in the latter. The appearance of miocene European forms in the pliocene Siwaliks, and the existence at the present day of mammals, like elephants and rhinoceroses, on land, and of numerous marine molluscan genera in the seas of India, long after they have disappeared from the European area, are additional examples. The cases are not sufficiently numerous to indicate any law of migration from north to south, nor is the tendency to survival in India universal; for, on the other hand, *Voltzia heterophylla* and the other Karharbári plants probably occurred in India before they appeared in Europe; and several genera of *Gasteropoda* that abound in the Indian upper cretaceous beds are not found in Europe in older rocks than eocene. Still the instances of survival of older forms in India are sufficiently numerous to be worthy of mention: how far they are due to the tropical position, or to the great antiquity of the land area, it is difficult to say.

Glacial epoch.—Amongst the most potent disturbing causes that have affected the fauna of India in late geological times, the general refrigeration of the area in the glacial epoch has in all probability played a conspicuous part. The former extension of the Himalayan glaciers has been shewn to have been considerable; and the occurrence of Himalayan plants and animals on the higher ranges of Southern India may be due to the retreat of these species in the first place towards the equator, and subsequently, as the temperature increased, to the higher parts of the hills. As examples, the occurrence of a Himalayan rhododendron, of a wild goat allied to a Himalayan species, and of several Himalayan land shells on the Nilgiri and other Southern Indian hills

may be mentioned. The isolation of such forms of the ancient Indo-African fauna as the *Simiidæ*, *Lemuridæ*, and *Tragulidæ* may have been due to the irruption of the Siwalik fauna, in pliocene times; whilst the latter, in its turn, has been impoverished, and to a great extent exterminated, by the increasing cold of the glacial epoch. It is easy to understand how the remaining descendants of the old miocene fauna may have been driven to the tropics, and that thus their absence in the northern part of the Oriental region has been caused. It is not impossible that the distinction between the Malabar and Malay faunas has been intensified by their separation, due to the climate of Northern India having been too cold for them in the glacial epoch.

Sub-recent changes of level.—The evidence of recent changes in elevation on the shores of the Indian Peninsula, and also to the westward, along the Makrán coast, and to the east of the Bay of Bengal, on the shores of Arakan and of the islands in the Bay, indicates a rise of land. In places depression to a small extent has also taken place; but this is unusual, and apparently local; it is singular, however, that evidence of depression is found in one instance, in Bombay Island,[1] within a mile or two of land, which has apparently been raised. The Sahyádri scarp, at a little distance from the west coast, has much the appearance of an ancient sea-cliff, and may perhaps indicate a former coast line; but this is far from certain. The circumstance, that the low-level laterite in the neighbourhood of both coasts rests upon a sloping plane of rock, apparently formed by marine denudation, in all probability indicates elevation at no distant period; the laterite in question being certainly post-tertiary on the east coast, and probably on the western also. The elevation on the west coast may probably have been greater than on the eastern, as the laterite near the coast is raised to a higher level; and in the great rivers running westward, the Tapti and Narbada, large plains of post-tertiary deposits are found, one of which certainly has been accumulated in a rock-basin, whilst no such plains are found in the rivers running eastward.

Along the Makrán coast, to the west of India, there is a sub-marine cliff, at a distance of about 10 to 20 miles from the shore. This cliff extends from a little west of Cape Monze to the entrance of the Persian Gulf, and is about 2,000 feet high; the depth of the sea increasing more or less suddenly from 20 or 30 fathoms to 300 or 400. Without further

[1] The evidence of depression has been noticed since pp. 375–377 were printed off, and consists of the discovery of a large number of trees, imbedded in mud on the spot where they grew, with their roots at a depth of twelve feet below low-water mark, on the eastern or harbour side of Bombay Island. Rec. G. S. I., XI, p. 302. Similar evidence was recorded, some years ago, by Dr. Buist.

details, it is difficult to say whether this sub-marine cliff indicates depression: such would be the natural interpretation of the phenomenon, and it is, on the whole, most probable that a former coast line of sea-cliffs has been depressed; but there is, in several places along the coast, evidence of recent elevation, in the shape of raised shell beds, &c., and there is a possibility that the line of sub-marine cliffs may be a fault. On the Arabian coast of the Gulf of Omán, however, about Muscat and the Straits of Hormuz, there is abundant evidence of depression at no distant period. The depressed area in the ocean south-west of India, as indicated by the Laccadive, Maldive, and Chagos atols, has already been noticed as possibly indicating the area of the ancient land communication between India and Africa.

Previous summaries of Indian geology: Calder, 1833.—Before concluding this Introduction, a brief notice of former general descriptions of Indian geology may be useful. Such general accounts are not numerous, and a reference to them will not take much space.

The earliest attempt at a sketch of Indian geology was written by Mr. James Calder, and forms the first paper of the Eighteenth Volume of the Asiatic Researches, published in 1833. This volume is chiefly composed of geological papers, and to these Mr. Calder's forms, as it were, an introduction. In this account, which occupies only 23 pages, the general distribution of the overlying trap formation in Western and Central India, and the great prevalence of granitic and gneissic formations both in the Peninsula and throughout the Himalayas, are correctly indicated; but, as might be anticipated, the knowledge of the sedimentary formations of India was at that time very imperfect. The writer passes the different provinces in review, noting what had been ascertained as to the rocks occurring in each case.

Newbold, 1844-1850.—The next account refers to the southern part of the Peninsula alone; but it is the work of one of the best, if not actually the best, of the earlier Indian geologists; and it has the peculiar advantage over all other summaries published up to the present time, that the author possessed an extensive personal acquaintance with the country described. Captain Newbold's Summary of the Geology of Southern India is published in Volumes VIII, IX, and XII of the Journal of the Royal Asiatic Society, and treats of the area south of Bombay and Ganjam. The various formations are classed as the Hypogene series (the metamorphic rocks of the present work); diamond sandstone and limestone (including the transition and Vindhyan series and some Gondwána beds); the fossiliferous limestone of Pondicherry (cretaceous); fresh-

water limestones and cherts (intercalated with the Deccan traps); laterite, with which are associated, in one section, the Pondicherry silicified wood deposit (Cuddalore sandstone) and the marine sandstone beds of Ramnád and Cape Comorin; older alluvium, including regur and kankar; modern alluvium and sand dunes; plutonic rocks (granite, greenstone, &c.); and newer or overlying trap.

The most important error in this classification was the association of the rocks now classed in the Gondwána system with the ancient "diamond sandstone" of transition or Vindhyan age. This appears due to Captain Newbold's having no personal knowledge of the Gondwána beds, and to their having been confounded with the older rocks by previous observers. Most of the observations recorded in the Summary are admirable; and altogether the paper is so valuable, that the neglect with which it has been generally treated, and the much greater notice attracted by Dr. Carter's account, are not easy to understand. Captain Newbold's observations will be frequently noticed in the present work.

Carter, 1854.—Dr. Carter's "Summary of the Geology of India between the Ganges, the Indus, and Cape Comorin," first published in 1854 in the Journal of the Bombay Branch of the Royal Asiatic Society, Vol. V, pp. 179–335, and republished with additional notes in 1857 in the author's very useful reprint of "Geological Papers on Western India," is a compilation of great merit, and is much more generally known, in India at all events, than Captain Newbold's description of the geology of Southern India; but it cannot be said to equal the latter, either in accuracy or originality. Dr. Carter's Summary treats of a larger area than Captain Newbold's—of the whole of Peninsular India, in fact; but it suffers from the serious disadvantage that the author was personally acquainted with but an extremely limited tract in Western India, that he had never seen the vast majority of Indian formations, and that he was compelled to take the whole of his description from other writers.

The rocks of the Indian Peninsula are classed by Dr. Carter in 13 sub-divisions: (1) The Primitive Plutonic Rocks; (2) Older Metamorphic Strata; (3) Secondary Plutonic Rocks; (4) Cambrian and Silurian Rocks of M'Clelland; (5) Oolitic Series; (6) Cretaceous System; (7) Eocene Formation; (8) Volcanic Rocks (Trappean System, first series); (9) Inter-trappean Lacustrine Formation; (10) Volcanic Rocks (Trappean System, 2nd series); (11) Miocene and Pliocene Formations; (12) Post-pliocene Period; (13) Recent Formations. This classification is inferior in accuracy to Captain Newbold's. It was an unfortunate mistake to class the Gondwána rocks with the Transition and Vindhyan formations; but it was still more erroneous to call the latter "oolitic." Dr. Carter, depending upon

the descriptions, tried to classify the different deposits of his "Oolitic series" in three groups, termed respectively Tara, Kattra, and Panna, from localities in Bundelkhand, and much confusion has hence arisen. The classification of the metamorphic rocks also is artificial; and the subdivision of the volcanic rocks into two series, the intercalation of the intertrappean lacustrine series between the two, and the position assigned to the eocene rocks below, instead of above the traps, have all proved to be incorrect. Even where Dr. Carter was personally acquainted with the rocks, his views have not always been confirmed by subsequent research. Thus the traps of Bombay and Salsette were classed as intrusive; whereas almost all other observers agree in considering these beds as resting regularly, with their intercalated sedimentary beds, upon the older lava flows of the Deccan; and there can be no doubt that this is the correct view, the dip of the Bombay beds being due to disturbance after their consolidation.

Attention is called to these grave errors in Dr. Carter's paper from no wish to criticise his work harshly, but because, owing to the numerous merits of the "Summary," his views have been widely accepted, and are still quoted as valid in recent works: for instance, in Dr. Leith's description of the geology of Bombay, just published in the *Bombay Gazetteer*. In many respects Dr. Carter's Summary was a most valuable compilation; and, with the exception of the mistake about the rocks of Bombay, all the errors were due to the imperfection of the observations from which the work was compiled. The labour of compiling a general description of Indian rocks from the fragmentary materials available at the time was very great; and by the compilation of his Summary, by the republication of the various geological papers on Western India, and by the collection of numerous valuable notes in the Journal of the Bombay Branch of the Royal Asiatic Society, Dr. Carter gave most important aid to Indian geology.

Greenough, 1854.—Mr. Greenough's Geological Map of India was exhibited to the British Association in 1854, and published shortly after. The author had endeavoured to combine all published information as to the distribution of Indian geological formations; and the result was a map which did represent fairly the areas occupied by some of the principal formations, such as the metamorphic rocks and the Deccan trap; but which, owing to the very imperfect knowledge available at the time, was deficient in details, even with respect to those formations, and which contained many errors both in topography and the distribution of the rocks. Still the map, although it does not quite represent the knowledge available at the time of its publication, is a very valuable record of the amount

procurable by a careful recorder working in Europe. In presenting the map to the British Association, Mr. Greenough gave a brief sketch of the rocks known to occur in India. This sketch will be found at page 83 of the transactions of the sections, in the Report of the Twenty-fourth Meeting of the British Association, published in 1855.

Later sketches.—Although the date of publication of the last two works, Carter's Summary and Greenough's Map, is posterior to that of the commencement of regular survey operations under the late Dr. Oldham, the work of surveying had commenced too short a time for the results to be appreciable; and the description and map named represent, the former more adequately than the latter, the knowledge of Indian geology existing when systematic surveying was commenced. Surveys of isolated tracts had previously been made by Captain Herbert, Mr. Williams, Dr. M'Clelland, Dr. Fleming, and others for Government; but the regular examination of the country can scarcely be said to have commenced before 1851, if indeed its origin should not be placed somewhat later. The only general descriptions since published are by various officers of the Survey. A digest of the geological information published up to the time was printed by Professor Martin Duncan for the use of students at Cooper's Hill College, but was not published. A brief sketch of Indian geology was given in Mr. H. F. Blanford's "Rudiments of Physical Geography for the use of Indian Schools." Lastly, whilst the present work has been passing through the press, Dr. Waagen, who, like Mr. H. F. Blanford, belonged formerly to the staff of the Indian Geological Survey, has published a short general description of the geology of India, entitled "Ueber die geographische Vertheilung der fossilen Organismen in Indien" in the "Denkschriften" of the Imperial Academy of Sciences, Vienna. All these papers are founded, like the present work, on the survey observations, and consequently require no detailed notice.